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National Air Pollutant Emission Estimates, 1940-1988

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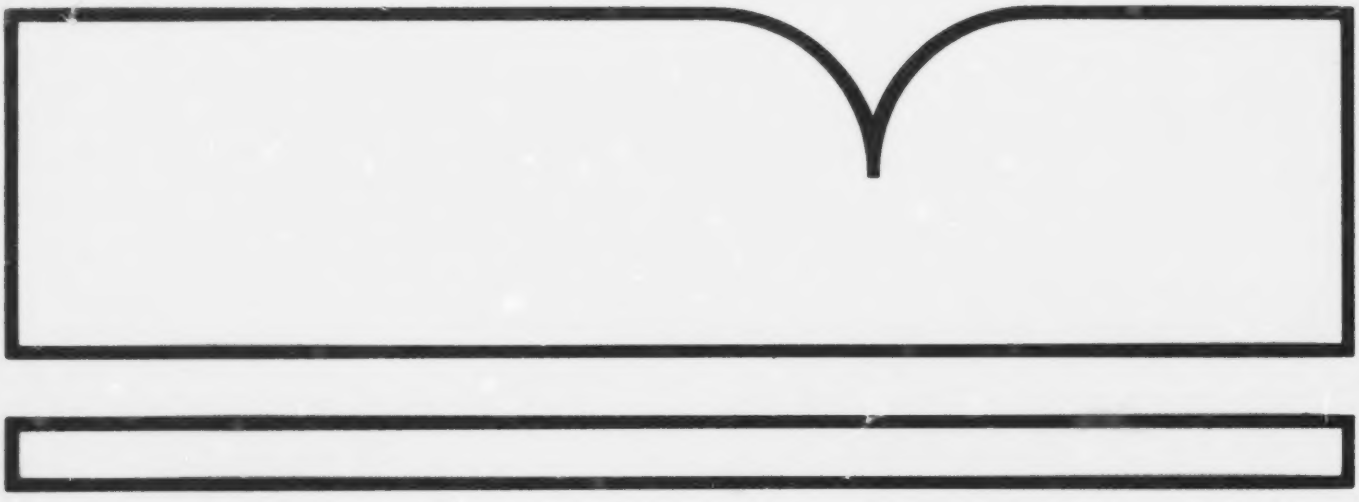

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This report presents estimates of trends in nationwide air pollutant emissions for six major pollutants: particulate (PM/TSP), sulfur oxides, nitrogen oxides, reactive volatile organic compounds, carbon monoxide, and lead. Estimates are provided for major categories of air pollution sources. A short analysis of emission trends is given, along with a discussion of methods used to develop the data.

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NATIONAL AIR POLLUTANT EMISSION ESTIMATES 1940 - 1988

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1940 - 1988

Technical Support Division
National Air Data Branch

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

MARCH 1990

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NATIONAL AIR POLLUTANT EMISSION ESTIMATES

1940-1988

1. SUMMARY

The primary objective of this publication is to provide current estimates of nationwide emissions for six major air pollutants: particulate with TSP as the indicator pollutant (PM/TSP), sulfur oxides (SO_x), nitrogen oxides (NO_x), reactive volatile organic compounds (VOC), carbon monoxide (CO) and lead (Pb). Estimates are presented for 1940, 1950, 1960, and 1970 to give an historical perspective of national air pollutant emissions, and for 1975 through 1988 as an indication of recent trends. These data entirely replace those published earlier for 1940-1970 and 1975-1987 in the Environmental Protection Agency report National Air Pollutant Emission Estimates, 1940-1987 (EPA-450/4-88-022). Because of modifications in methodology and use of more refined emission factors, data from this report should not be compared with data in the earlier report.

Reporting of emissions on a nationwide basis, while useful as a general indicator of trends in emissions, has definite limitations. National totals or averages are not the best guide for estimating trends for particular localities. Yet, it is important that some criteria be established for reporting national progress in the control of air pollutant emissions. The emission estimates presented in this document represent calculated estimates based on standard emissions-estimating procedures. Since these data are estimates and do not represent the results of any program for the measurement of actual emissions, their accuracy is limited. Similarly, these emission estimates would not necessarily be in agreement with emission estimates derived through a different emissions-estimating procedure. The principal objective of compiling these data is to identify probable overall changes in emissions on a national scale. It should be recognized that these estimated national trends in emissions are not meant to be representative of local trends in emissions or air quality.

TABLE 1*

SUMMARY OF ESTIMATES OF NATIONWIDE EMISSIONS

Pollutant (Teragrams/Year)	1940	1950	1960	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988
Particulate (PM/TSP)	23.1	24.9	21.6	18.5	10.6	8.5	8.0	7.1	7.1	7.4	7.1	6.8	7.0	6.9
Sulfur Oxides	17.6	19.8	19.7	28.3	25.8	23.4	22.6	21.4	20.7	21.5	21.1	20.9	20.6	20.7
Nitrogen Oxides	6.9	9.4	13.0	18.5	19.5	20.9	20.9	20.0	19.3	19.8	19.8	19.0	19.3	19.8
Reactive Volatile Organic Compounds	15.2	18.1	21.0	25.0	21.1	21.1	19.8	18.4	19.3	20.3	19.1	18.3	18.6	18.6
Carbon Monoxide	82.6	87.6	89.7	101.4	84.1	79.6	77.4	72.4	74.5	71.8	67.0	63.1	64.1	61.2
Lead (Gigagrams/Year)	NA	NA	NA	203.8	147.0	70.6	56.4	54.4	46.4	40.1	21.1	8.6	8.0	7.6

Pollutant (10*6 Short Tons/Year)	1940	1950	1960	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988
Particulate (PM/TSP)	25.5	27.4	23.8	20.4	11.6	9.4	8.8	7.8	7.8	8.1	7.8	7.5	7.7	7.6
Sulfur Oxides	19.4	21.8	21.7	31.2	28.5	25.8	24.9	23.6	22.8	23.7	23.3	23.0	22.8	22.8
Nitrogen Oxides	7.6	10.4	14.3	20.4	21.5	23.1	23.1	22.1	21.3	21.9	21.9	21.0	21.3	21.8
Reactive Volatile Organic Compounds	16.8	20.0	23.1	27.5	23.2	23.3	21.8	20.3	21.2	22.4	21.1	20.1	20.5	20.5
Carbon Monoxide	91.1	96.6	98.9	111.8	92.7	87.8	85.3	79.8	82.1	79.1	73.9	69.5	70.7	67.4
Lead (10*3 Short Tons/Year)	NA	NA	NA	224.6	162.1	77.8	62.2	60.0	51.2	44.2	23.3	9.5	8.8	8.4

Pollutant	% Change 1940-88	% Change 1970-88	% Change 1980-1988	% Change 1987-1988
Particulate (PM/TSP)	-70	-63	-19	-1
Sulfur Oxides	18	-27	-12	<1
Nitrogen Oxides	187	7	-5	3
Reactive Volatile Organic Compounds	22	-26	-12	0
Carbon Monoxide	-26	-40	-23	-5
Lead	N/A	-96	-89	-5

*Tables 1-29:

One teragram equals 10^{12} grams (10^6 metric tons) or approximately 1.1 x 10^6 short tons (2000 lbs.).
One gigagram equals 10^9 grams (10^3 metric tons) or approximately 1.1 x 10^3 short tons (2000 lbs.).
A value of zero indicates emissions of less than 50,000 metric tons.

2 . NATIONWIDE EMISSION TRENDS, 1940-1988

Table 1 presents a summary of total national emission estimates for 1940-1988. Figures 1 through 6 depict how total emissions and emissions from major source categories have changed over time for each pollutant. Tables 2 through 12 present more detailed summaries for each year according to five major categories of sources: transportation, stationary source fuel combustion, industrial processes, solid waste disposal, and miscellaneous sources. Detailed breakdowns of emissions for 1970 through 1988 are given in Tables 13 through 17 for transportation, Tables 18 through 22 for stationary source fuel combustion, and in Tables 23 through 28 for industrial processes.

The Standard Industrial Classifications (SIC) are shown for each process category in the industrial process tables. These estimates do not represent the complete emissions for all SIC categories--only those particular industrial processes shown.

In all tables, data are reported in metric units, either as teragrams (10^{12} grams) or gigagrams (10^{9} grams) per year. One teragram equals 10^{6} metric tons and approximately 1.1×10^{6} short tons (2000 lbs.). One gigagram equals 10^{3} metric tons and approximately 1.1×10^{3} short tons.

Figures 7 through 12 show how the relative contribution of the major source categories to the total emissions of each pollutant have changed with time. The major factors influencing these changes for each pollutant are discussed briefly below. A more detailed discussion appears in Chapter 4.

2.1 Particulate (PM/TSP)

Emissions of particulate (PM/TSP) result primarily from sources of fugitive dust. Fugitive particulate emissions (emissions from uncontrolled sources such as storage piles, material loading, etc.) are incompletely accounted for in the emission totals. Rough estimates of industrial process fugitive emissions are included for some industries. Area source fugitive dust emissions (unpaved roads, construction activities, etc.) are not included at all; based on data in the National Emissions Data System (NEDS), the 1986 particulate emissions from these sources were estimated to be 25.6 million metric tons (28.2 million short tons) or about 76% of the total national emissions of PM/TSP in 1986. Similarly, natural sources of particulate emissions such as wind erosion or dust, are not included. (An exception is forest fires, some of which result from natural causes). In total, these fugitive emissions may amount to a considerable portion of total particulate emissions. The controls applied to these sources have so far been minimal. Due to the lack of adequate emission factors and emission inventory techniques for these sources, fugitive particulate emissions have not been included in most emission inventories. As additional data become available, it is expected that estimates of fugitive particulate emissions will be included in future emission inventories. It should be noted, however, that a major portion of the fugitive particulate emissions are relatively large particles that are not readily captured by particulate air quality monitors. Similarly, these large particles do not effectively enter into the human respiratory system.

In 1940 and 1950, emissions from transportation (coal combustion by railroads) and miscellaneous sources (forest fires) were significant. Emissions from fuel combustion and industrial processes did not change substantially from 1940 to 1970. Since 1970, emissions from these categories have been substantially reduced as a result of the installation of air pollution control equipment. Particulate emissions from transportation decreased substantially from 1940 to 1960 as the result of the obsolescence of coal-burning railroad locomotives. From 1960 to 1988, particulate from transportation increased due to increased travel by highway motor vehicles. Miscellaneous source emissions decreased substantially from 1940 to 1970, primarily due to a major reduction in the acreage burned by forest wildfires. Solid waste emissions increased from 1940 to 1970, but declined substantially to 1988 as the result of air pollution regulations prohibiting or limiting the burning of solid waste.

2.2 Sulfur Oxides (SO_x)

Emissions of sulfur oxides occur mostly from stationary source fuel combustion and to some extent, from industrial processes. Emissions of sulfur oxides from the combustion of coal by railroad locomotives were significant in 1940 and 1950. Emissions from solid waste disposal and miscellaneous sources have always been minor. Emissions from stationary source fuel combustion increased greatly from 1940 to 1970. From 1970 to 1988, emissions from fuel combustion have decreased slightly. During this time period, fuel combustion, particularly of sulfur-bearing coal, continued to increase, but the average sulfur contents of fuels decreased and an increasing number of pollution control systems (flue gas desulfurization) were installed. Emissions from industrial processes increased from 1940 to 1970 reflecting increased industrial production. From 1970 to 1987, industrial process emissions decreased primarily due to control measures by primary non-ferrous smelters and sulfuric acid plants. Increased industrial activity in refining, metals, minerals, and chemicals led to a slight increase (6 percent) in emissions from 1987 to 1988.

2.3 Nitrogen Oxides (NO_x)

Emissions of nitrogen oxides are produced largely by stationary source fuel combustion and by transportation sources. Emissions have steadily increased over the period from 1940 to 1970 as the result of increased fuel combustion. From 1970 to 1988, the size of the increase was reduced somewhat by controls installed on highway motor vehicles and to a lesser extent by controls on coal-fired electric utility boilers. From 1978-1983, NO_x emissions decreased slightly. Since then, NO_x emissions have increased, but remain below the 1978 peak. Emissions of nitrogen oxides by industrial processes increased from 1940 to 1970, but have remained about constant since then.

2.4 Reactive Volatile Organic Compounds (VOC)

The largest sources of reactive VOC emissions are transportation sources and industrial processes. Miscellaneous sources, primarily forest wildfires and non-industrial consumption of organic solvents, also contribute significantly to total VOC emissions. Emissions from stationary source fuel combustion and solid waste disposal are relatively small. Transportation source emissions increased greatly from 1940 to 1970, primarily as the result of increased travel by highway motor vehicles. Since 1970, air pollution controls installed on motor vehicles have been effective in reducing VOC emissions. Industrial process emissions have increased through the late 70's, generally reflecting increased levels of industrial production. Controls installed on industrial processes since 1970 have had a modest effect in preventing additional increases in VOC emissions. Since 1979, VOC emissions from industrial processes have decreased. This reflects both the installation of controls and a lower level of industrial output during 1980-1983. However, during 1987-1988 industrial activity increased which led to a slight increase in emissions (2 percent). Emissions from stationary source combustion declined from 1940 through the mid-1970's and then increased to 1984, reflecting primarily the trend in residential wood combustion.

2.5 Carbon Monoxide (CO)

Transportation sources are the largest emitters of carbon monoxide. Major increases in emissions occurred from 1940 to 1970 as the result of increased motor vehicle travel. From 1970 to 1988, transportation emissions decreased as the result of highway vehicle emission controls, despite continued increases in highway vehicle travel. Emissions from stationary source fuel combustion have declined from 1940 through the mid-1970's and then increased slightly in 1987.

Prior to 1970, residential coal and wood combustion contributed significantly to CO emissions. However, as residential use of coal has been replaced by other fuels, residential emissions have declined. Beginning in the late 1970's, residential combustion of wood has increased, however, and as a result CO emissions from residential fuel combustion increased. Carbon monoxide emissions from industrial processes increased from 1940 to 1950 but have declined somewhat since then. The decline is due largely to the obsolescence of a few high-polluting industrial processes such as carbon black manufacture by the channel process and limited installation of control equipment on other processes. These factors have been significant enough to offset growth in industrial production which would otherwise have caused a net increase in emissions. However, due to increased industrial activity in 1988 emissions from 1987 to 1988 increased slightly (4 percent). Carbon monoxide emissions from solid waste disposal increased from 1940 to 1970, but have subsequently declined as the result of air pollution control efforts. Substantial emissions of carbon monoxide from forest fires occurred in 1940. In later years, these emissions have been much smaller due to improved fire prevention efforts and more effective suppression of wildfires.

2.6 Lead (Pb)

The primary sources of lead emissions are transportation (gasoline engines) and industrial processes. This report does not include estimates of lead emissions for 1940, 1950 or 1960 because of missing data, especially for transportation sources. In the early 1970's, the transportation emissions varied based on the amount of gasoline consumed and the average lead content. From 1975 to 1987, transportation emissions decreased as a result of the conversion to unleaded gasoline. A major reduction occurred between 1984 and 1986 due to EPA rule-making which required petroleum refiners to lower the lead content of leaded gasoline in 1985. Emissions from industrial processes have declined from 1970 to 1987 as the result of installation of air pollution control equipment. However, due to increased industrial activity in 1988 emissions from 1987 to 1988 increased slightly (5 percent).

Figure 1

Trends in Emissions of Particulate (PM/TSP), 1940-1988

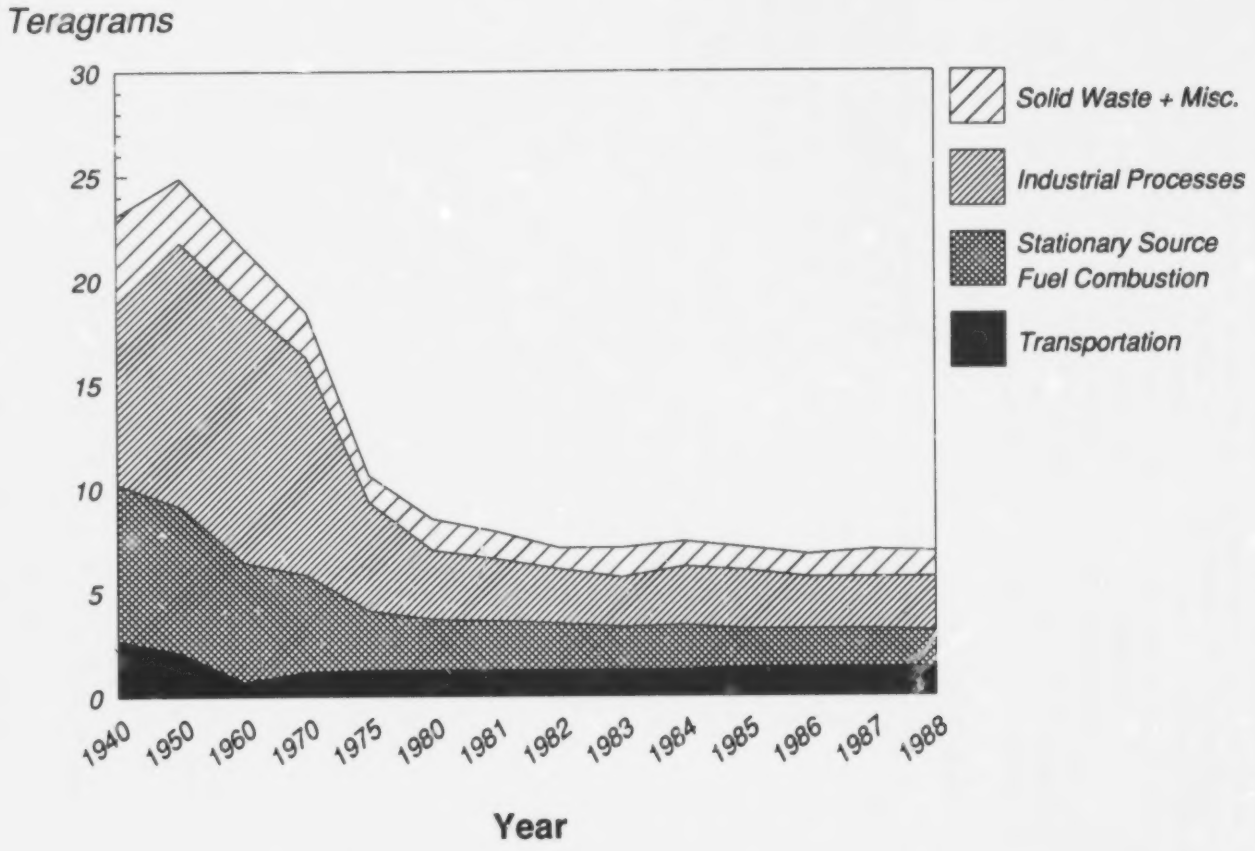


Figure 2

Trends in Emissions of Sulfur Oxides, 1940-1988

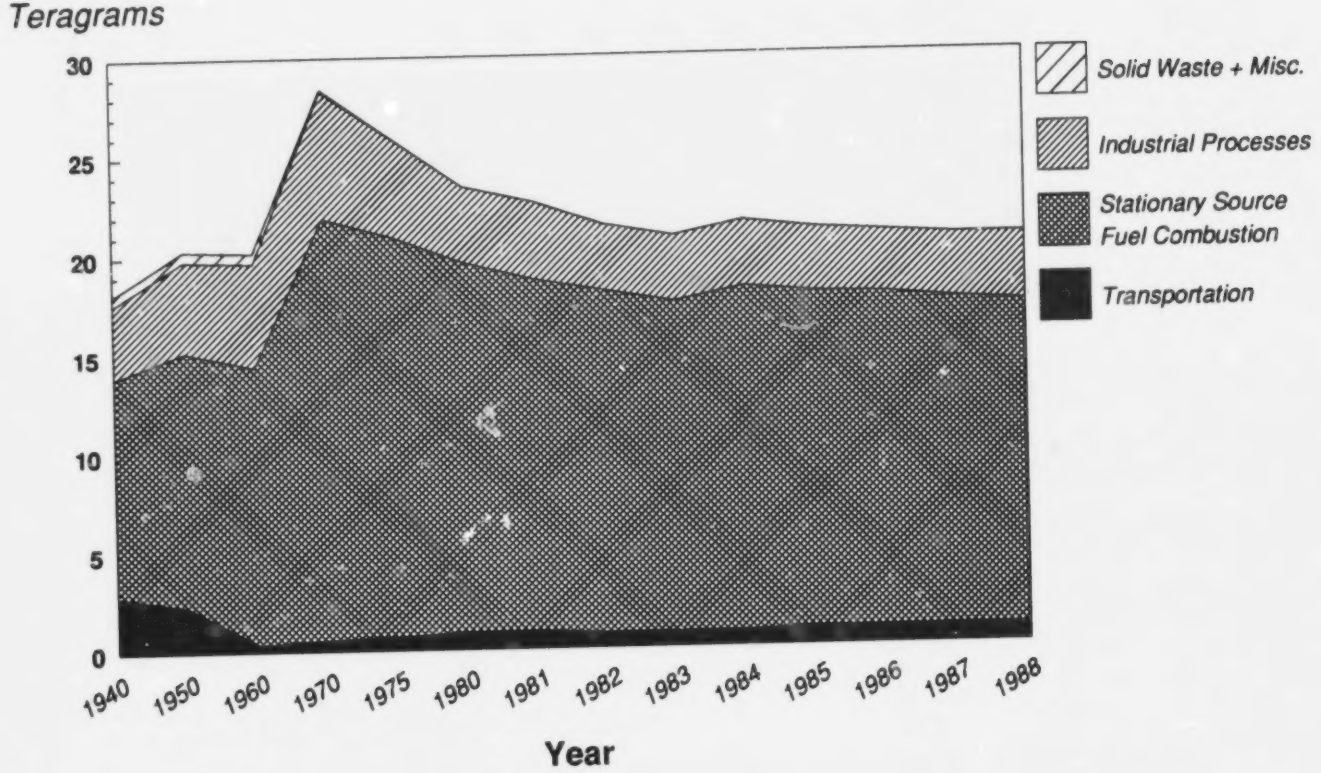


Figure 3

Trends in Emissions of Nitrogen Oxides, 1940-1988

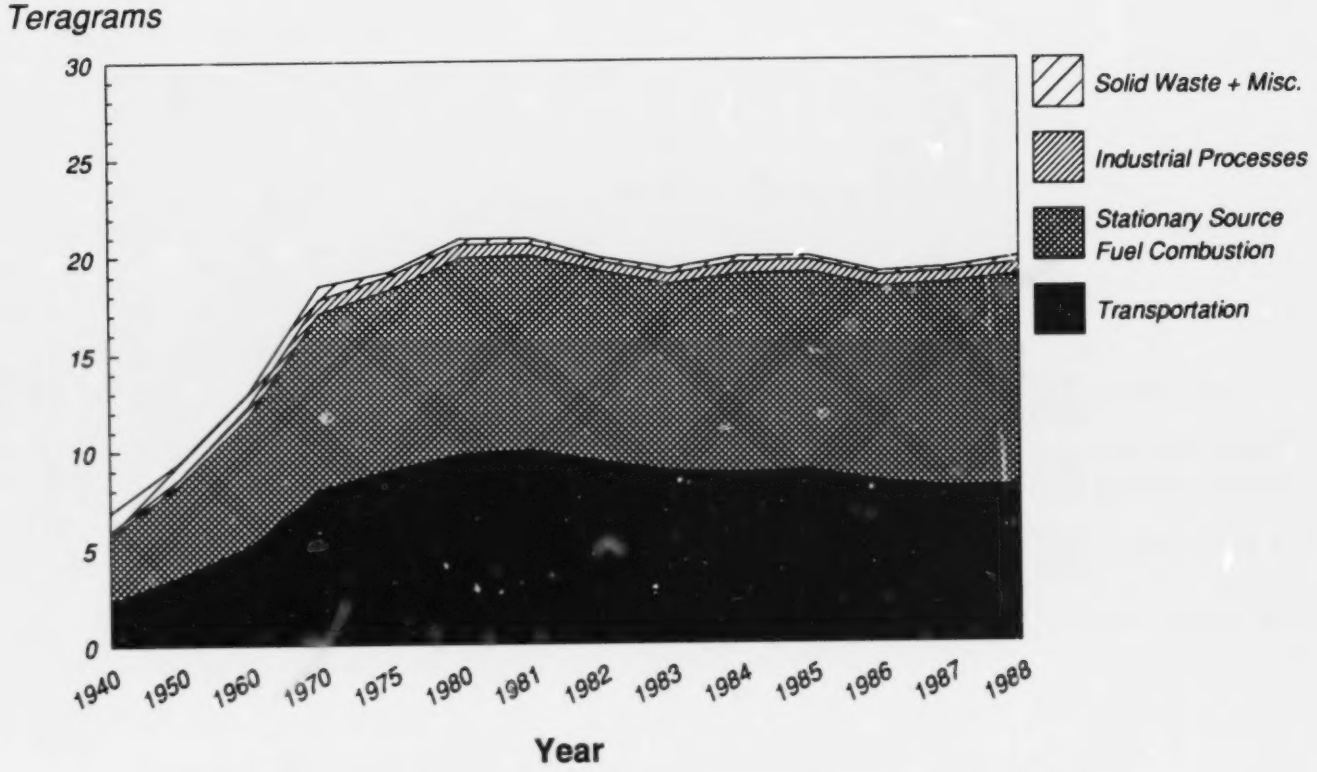


Figure 4

Trends in Emissions of Reactive Volatile Organic Compounds, 1940-1988

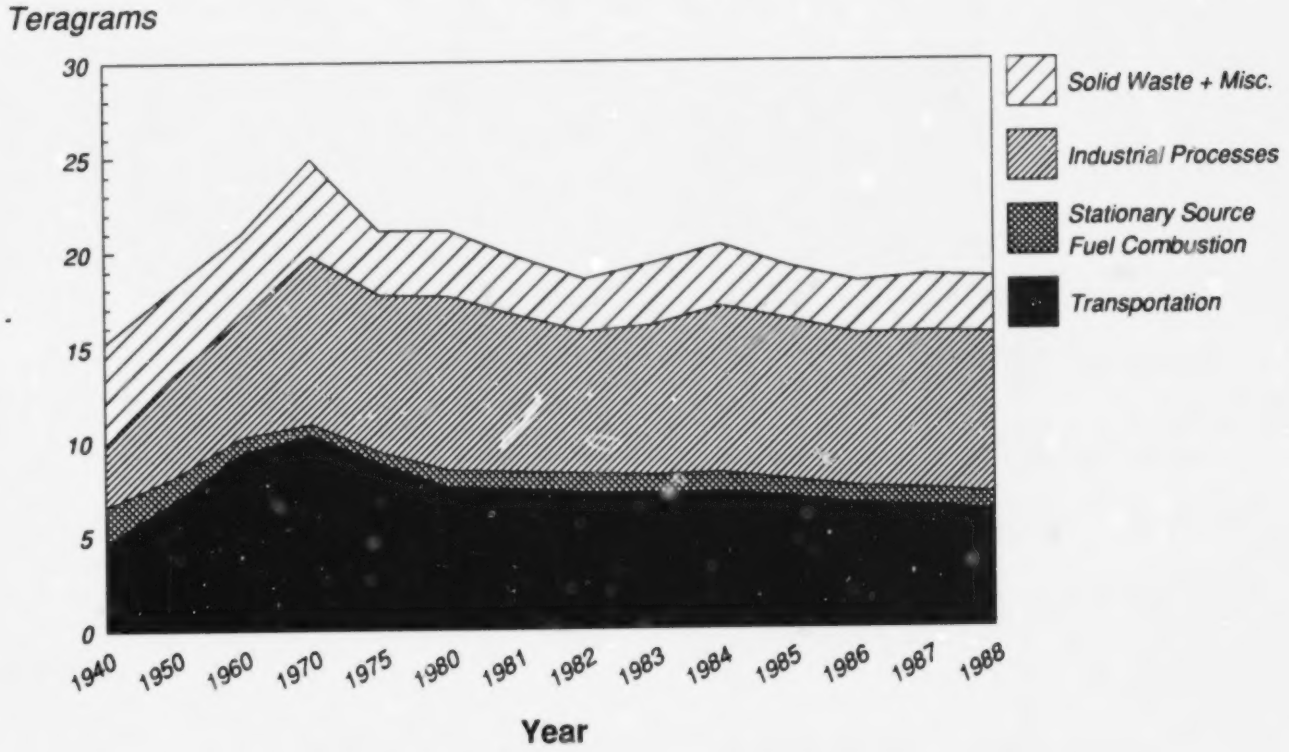


Figure 5

Trends in Emissions of Carbon Monoxide, 1940-1988

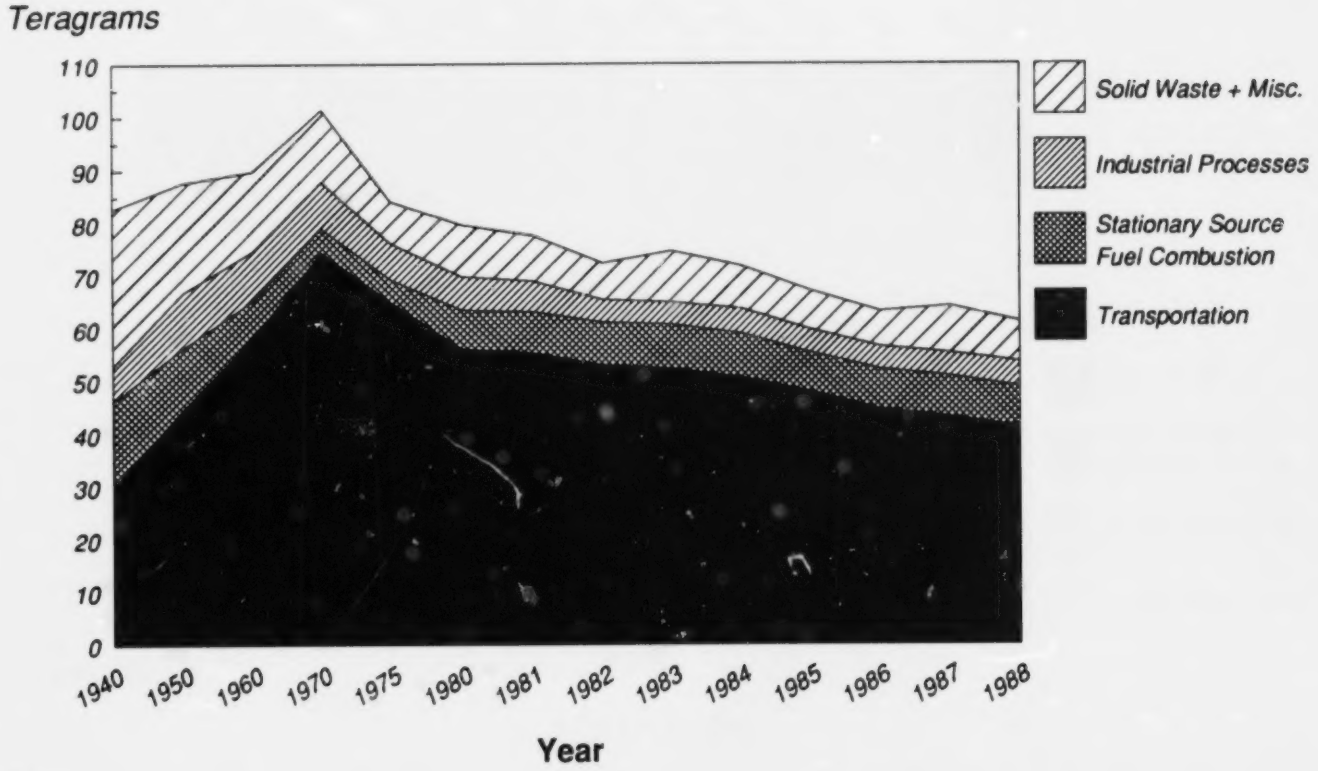


Figure 6

Trends in Emissions of Lead, 1970-1988

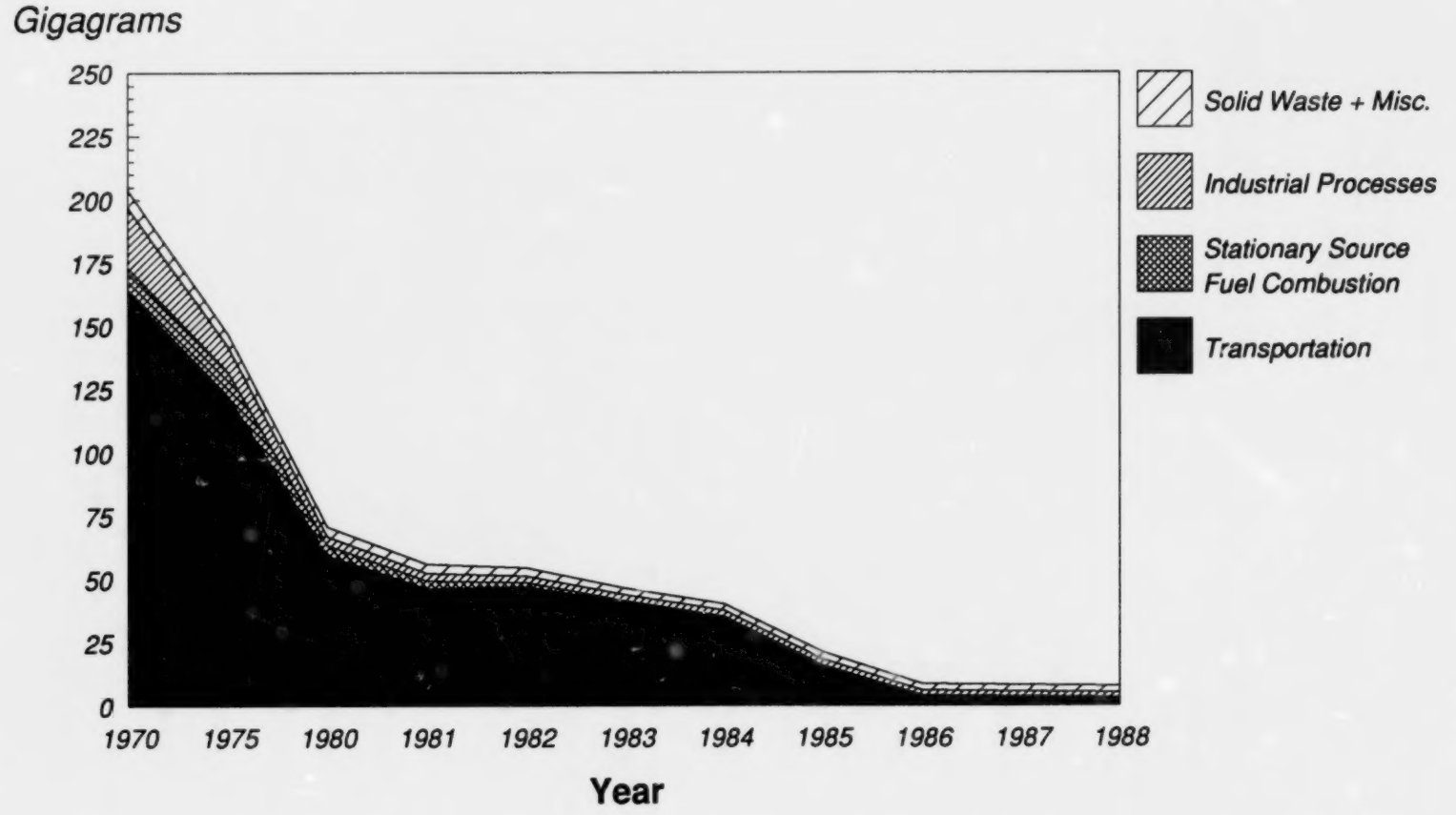


TABLE 2

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF PARTICULATE (PM/TSP) (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	0.2	0.3	0.6	0.9
Aircraft	0.0	0.0	0.0	0.1
Railroads	2.4	1.7	0.1	0.1
Vessels	0.1	0.1	0.0	0.0
Other-Off Highway	0.0	0.0	0.0	0.1
Transportation Total	2.7	2.1	0.7	1.2
Stationary Source Fuel Combustion				
Electric Utilities	1.3	2.0	2.8	2.3
Industrial	3.3	2.8	1.8	1.6
Commercial-Institutional	0.4	0.5	0.1	0.1
Residential	2.5	1.7	1.0	0.6
Fuel Combustion Total	7.5	7.0	5.7	4.6
Industrial Processes				
Iron and Steel Mills	3.0	3.5	1.7	1.2
Primary Metal Smelting	0.6	0.6	0.5	0.6
Secondary Metals	0.2	0.3	0.2	0.2
Mineral Products	2.0	2.9	3.8	2.9
Chemicals	0.3	0.4	0.3	0.2
Petroleum Refining	0.0	0.0	0.1	0.1
Wood Products	0.5	0.8	0.9	0.7
Food and Agriculture	0.8	0.8	0.9	0.8
Mining Operations	1.3	3.4	4.1	3.9
Industrial Processes Total	8.7	12.7	12.5	10.5
Solid Waste Disposal				
Incineration	0.3	0.3	0.4	0.4
Open Burning	0.2	0.3	0.5	0.7
Solid Waste Total	0.5	0.6	0.9	1.1
Miscellaneous				
Forest Fires	2.9	1.7	1.0	0.7
Other Burning	0.8	0.8	0.8	0.4
Misc. Total	3.7	2.5	1.8	1.1
Total of All Sources	23.1	24.9	21.6	18.5

TABLE 3

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF SULFUR OXIDES (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	0.0	0.1	0.1	0.3
Aircraft	0.0	0.0	0.0	0.0
Railroads	2.7	2.0	0.2	0.1
Vessels	0.2	0.2	0.1	0.2
Other-Off Highway	0.0	0.0	0.0	0.1
Transportation Total	2.9	2.3	0.4	0.6
Stationary Source Fuel Combustion				
Electric Utilities	2.2	4.1	8.4	15.8
Industrial	5.5	5.2	3.5	4.1
Commercial-Institutional	1.0	1.7	1.0	0.9
Residential	2.3	1.9	1.1	0.5
Fuel Combustion Total	11.0	12.9	14.0	21.3
Industrial Processes				
Primary Metal Smelting	2.5	2.8	3.0	3.7
Pulp Mills	0.0	0.0	0.1	0.2
Chemicals	0.2	0.4	0.4	0.5
Petroleum Refining	0.2	0.3	0.6	0.7
Iron and Steel	0.5	0.6	0.6	0.7
Secondary Metals	0.0	0.0	0.0	0.0
Mineral Products	0.3	0.5	0.5	0.6
Natural Gas Processing	0.0	0.0	0.1	0.1
Industrial Processes Total	3.7	4.6	5.3	6.4
Solid Waste Disposal				
Incineration	0.0	0.0	0.0	0.0
Open Burning	0.0	0.0	0.0	0.0
Solid Waste Total	0.0	0.0	0.0	0.0
Miscellaneous				
Forest Fires	0.0	0.0	0.0	0.0
Other Burning	0.5	0.5	0.5	0.1
Misc. Total	0.5	0.5	0.5	0.1
Total of All Sources	17.6	19.8	19.7	28.3

TABLE 4

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF NITROGEN OXIDES (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	1.4	2.2	3.8	6.3
Aircraft	0.0	0.0	0.0	0.1
Railroads	0.6	0.9	0.7	0.6
Vessels	0.1	0.1	0.1	0.1
Other-Off Highway	0.2	0.4	0.5	0.8
Transportation Total	2.3	3.6	5.1	8.0
Stationary Source Fuel Combustion				
Electric Utilities	0.6	1.2	2.3	4.4
Industrial	2.3	2.9	3.7	3.9
Commercial-Institutional	0.2	0.3	0.3	0.3
Residential	0.3	0.3	0.4	0.4
Fuel Combustion Total	3.4	4.7	6.7	9.1
Industrial Processes				
Petroleum Refining	0.1	0.1	0.2	0.2
Chemicals	0.0	0.0	0.1	0.2
Iron and Steel Mills	0.0	0.1	0.1	0.1
Pulp Mills	0.0	0.0	0.0	0.0
Mineral Products	0.1	0.1	0.1	0.2
Industrial Processes Total	0.2	0.3	0.5	0.7
Solid Waste Disposal				
Incineration	0.0	0.1	0.1	0.1
Open Burning	0.1	0.1	0.2	0.3
Solid Waste Total	0.1	0.2	0.3	0.4
Miscellaneous				
Forest Fires	0.7	0.4	0.2	0.2
Other Burning	0.2	0.2	0.2	0.1
Misc. Total	0.9	0.6	0.4	0.3
Total of All Sources	6.9	9.4	13.0	18.5

TABLE 5

1940-1970 SUMMARY OF ESTIMATED
EMISSIONS OF REACTIVE VOCS
(TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	4.0	5.7	8.3	9.1
Aircraft	0.0	0.1	0.2	0.3
Railroads	0.5	0.5	0.2	0.2
Vessels	0.0	0.1	0.2	0.3
Other-Off Highway	0.2	0.4	0.5	0.5
Transportation Total	4.7	6.8	9.4	10.3
Stationary Source Fuel Combustion				
Electric Utilities	0.0	0.0	0.0	0.0
Industrial	0.1	0.1	0.1	0.1
Commercial-Institutional	0.0	0.0	0.0	0.0
Residential	1.7	1.2	0.7	0.4
Fuel Combustion Total	1.8	1.3	0.8	0.6
Industrial Processes				
Chemicals	0.8	1.2	1.1	1.6
Petroleum Refining	0.4	0.5	0.7	0.7
Iron and Steel Mills	0.3	0.4	0.3	0.4
Mineral Products	0.0	0.0	0.0	0.0
Food and Agriculture	0.1	0.1	0.2	0.2
Industrial Organic Solvent Use	1.0	2.1	2.4	4.0
Petroleum Product Production and Marketing	0.7	1.1	1.6	2.1
Industrial Processes Total	3.3	5.4	6.3	8.9
Solid Waste Disposal				
Incineration	0.4	0.4	0.5	0.5
Open Burning	0.5	0.6	0.9	1.3
Solid Waste Total	0.9	1.0	1.4	1.8
Miscellaneous				
Forest Fires	3.1	1.7	0.9	0.7
Other Burning	0.6	0.6	0.5	0.3
Misc. Organic Solvent Use	0.8	1.3	1.7	2.3
Misc. Total	4.5	3.6	3.1	3.3
Total of All Sources	15.2	18.1	21.0	25.0

TABLE 6

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF CARBON MONOXIDE (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation	22.6	34.2	47.7	65.3
Highway Vehicles	0.0	0.8	1.6	0.9
Aircraft	3.7	2.8	0.3	0.3
Railroads	0.2	0.2	0.6	1.2
Vessels	3.4	6.7	8.0	6.8
Other-Off Highway				
Transportation Total	29.9	44.7	58.2	74.4
Stationary Source Fuel Combustion	0.0	0.1	0.1	0.2
Electric Utilities	0.4	0.5	0.6	0.7
Industrial	0.1	0.1	0.0	0.1
Commercial-Institutional	15.8	10.9	6.4	3.5
Residential				
Fuel Combustion Total	16.3	11.6	7.1	4.5
Industrial Processes	3.8	5.3	3.6	3.1
Chemicals	0.2	2.4	2.8	2.0
Petroleum Refining	1.5	1.1	1.3	1.6
Iron and Steel Mills	0.0	0.1	0.3	0.6
Primary Metal Smelting	1.0	1.4	1.0	1.1
Secondary Metals	0.1	0.2	0.3	0.6
Pulp Mills				
Industrial Processes Total	6.6	10.5	9.3	8.9
Solid Waste Disposal	2.0	2.5	2.5	2.7
Incineration	1.3	1.8	2.6	3.7
Open Burning				
Solid Waste Total	3.3	4.3	5.1	6.4
Miscellaneous	22.8	12.8	6.7	5.1
Forest Fires	3.7	3.7	3.3	2.1
Other Burning				
Misc. Total	26.5	16.5	10.0	7.2
Total of All Sources	82.6	87.6	89.7	101.4

TABLE 7

ESTIMATES OF NATIONAL EMISSIONS OF PARTICULATE (PM/TSP)
(TERAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation													
Highway Vehicles	0.9	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.1	1.1	1.1	1.1	1.1
Aircraft	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Railroads	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Vessels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other-Off Highway	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Transportation Total	1.2	1.3	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4
Stationary Source Fuel Combustion													
Electric Utilities	2.3	1.5	1.2	1.0	0.8	0.7	0.6	0.6	0.6	0.4	0.4	0.4	0.4
Industrial	1.6	0.6	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2
Commercial-Institutional	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Residential	0.6	0.5	0.8	0.9	1.0	1.0	1.1	1.1	1.2	1.0	1.0	1.0	1.0
Fuel Combustion Total	4.6	2.8	2.5	2.5	2.4	2.3	2.2	2.0	2.1	1.8	1.8	1.8	1.7
Industrial Processes	10.5	5.2	4.0	3.8	3.3	3.0	2.6	2.4	2.8	2.5	2.5	2.5	2.6
Solid Waste Disposal													
Incineration	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Open Burning	0.7	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Solid Waste Total	1.1	0.6	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Miscellaneous													
Forest Fires	0.7	0.6	0.7	0.8	1.0	0.8	0.6	1.0	0.8	0.7	0.7	0.9	0.8
Other Burning	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Misc. Organic Solvent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. Total	1.1	0.7	0.8	0.9	1.1	0.9	0.7	1.1	0.9	0.8	0.8	1.0	0.9
Total of All Sources	18.5	10.6	9.1	8.9	8.5	8.0	7.1	7.1	7.4	7.1	6.8	7.0	6.9

TABLE 8

ESTIMATES OF NATIONAL EMISSIONS OF SULFUR OXIDES
(TERAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation													
Highway Vehicles	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6
Aircraft	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Railroads	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Vessels	0.2	0.1	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other-Off Highway	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Transportation Total	0.6	0.7	0.8	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9
Stationary Source Fuel Combustion													
Electric Utilities	15.8	16.6	15.7	16.0	15.5	14.7	14.2	14.0	14.5	14.2	13.9	13.7	13.6
Industrial	4.1	2.7	2.7	2.7	2.4	2.3	2.3	2.0	2.2	2.2	2.3	2.2	2.1
Commercial-Institutional	0.9	0.7	0.7	0.6	0.7	0.6	0.6	0.4	0.5	0.4	0.5	0.5	0.5
Residential	0.5	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fuel Combustion Total	21.3	20.2	19.5	19.5	18.7	17.8	17.3	16.7	17.4	17.0	16.9	16.6	16.4
Industrial Processes	6.4	5.0	4.3	4.4	3.8	3.9	3.3	3.3	3.3	3.2	3.1	3.2	3.4
Solid Waste Disposal													
Incineration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open Burning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solid Waste Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous													
Forest Fires	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Burning	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. Organic Solvent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. Total	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total of All Sources	28.4	25.8	24.6	24.8	23.4	22.6	21.4	20.7	21.5	21.1	20.9	20.6	20.7

TABLE 9

ESTIMATES OF NATIONAL EMISSIONS OF NITROGEN OXIDES
(TERAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation													
Highway Vehicles	6.3	7.6	8.2	8.0	7.9	8.0	7.6	7.2	6.9	7.0	6.4	6.2	6.1
Aircraft	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Railroads	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.5	0.6	0.5	0.5	0.5	0.6
Vessels	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other-Off Highway	0.8	0.9	1.1	1.1	1.0	0.9	0.9	0.9	1.0	1.0	1.1	1.0	1.1
Transportation Total	8.0	9.3	10.3	10.1	9.8	10.0	9.4	8.9	8.8	8.9	8.3	8.0	8.1
Stationary Source Fuel Combustion													
Electric Utilities	4.4	5.2	5.8	6.1	6.4	6.4	6.2	6.3	6.6	6.8	6.6	6.9	7.1
Industrial	3.9	3.5	3.7	3.6	3.1	3.0	3.1	2.7	3.0	2.8	2.8	3.0	3.1
Commercial-Institutional	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Residential	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Fuel Combustion Total	9.1	9.3	10.3	10.5	10.1	10.0	9.8	9.6	10.2	10.2	10.0	10.5	10.8
Industrial Processes	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Solid Waste Disposal													
Incineration	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open Burning	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solid Waste Total	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Miscellaneous													
Forest Fires	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2
Other Burning	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. Organic Solvent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. Total	0.3	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2
Total of All Sources	18.5	19.5	21.7	21.6	20.9	20.9	20.0	19.3	19.8	19.8	19.0	19.3	19.8

TABLE 10

ESTIMATES OF NATIONAL EMISSIONS OF REACTIVE VOLATILE ORGANIC COMPOUNDS
(TERAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation													
Highway Vehicles	9.1	7.5	7.3	6.8	6.2	6.2	6.0	6.0	5.9	5.7	5.3	5.1	4.9
Aircraft	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Railroads	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Vessels	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5
Other-Off Highway	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5
Transportation Total	10.3	8.8	8.6	8.0	7.5	7.4	7.2	7.1	7.2	6.9	6.5	6.4	6.1
Stationary Source Fuel Combustion													
Electric Utilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Commercial-Institutional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential	0.4	0.4	0.6	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7
Fuel Combustion Total	0.6	0.6	0.8	0.9	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9	0.9
Industrial Processes	8.9	8.3	9.9	9.9	9.2	8.3	7.5	7.9	8.8	8.5	8.1	8.3	8.5
Solid Waste Disposal													
Incineration	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Open Burning	1.3	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Solid Waste Total	1.8	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Miscellaneous													
Forest Fires	0.7	0.5	0.7	0.8	0.9	0.8	0.6	1.0	0.8	0.6	0.6	0.8	0.7
Other Burning	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Misc. Organic Solvent	2.3	1.9	1.9	2.0	1.9	1.6	1.5	1.6	1.8	1.5	1.5	1.5	1.6
Misc. Total	3.3	2.5	2.7	2.9	2.9	2.5	2.2	2.7	2.7	2.2	2.2	2.4	2.4
Total of All Sources	25.0	21.1	22.8	22.4	21.1	19.8	18.4	19.3	20.3	19.1	18.3	18.6	18.6

TABLE 11

ESTIMATES OF NATIONAL EMISSIONS OF CARBON MONOXIDE
(TERAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation													
Highway Vehicles	65.3	57.2	55.6	51.9	48.7	48.0	45.9	45.9	43.5	40.7	37.5	36.0	34.1
Aircraft	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1
Railroads	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vessels	1.2	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.7	1.4	1.5	1.6	1.6
Other-Off Highway	6.8	5.4	4.8	4.5	4.7	4.7	4.4	3.9	4.2	4.5	4.4	4.4	4.2
Transportation Total	74.4	65.0	63.1	59.1	56.1	55.4	52.9	52.4	50.6	47.9	44.6	43.2	41.2
Stationary Source Fuel Combustion													
Electric Utilities	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Industrial	0.7	0.7	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Commercial-Institutional	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residential	3.5	3.3	4.8	5.7	6.4	6.7	7.3	7.2	7.3	6.5	6.6	6.6	6.6
Fuel Combustion Total	4.5	4.3	5.9	6.7	7.4	7.7	8.2	8.2	8.3	7.4	7.5	7.6	7.6
Industrial Processes	8.9	6.9	7.2	7.1	6.3	5.9	4.3	4.3	4.7	4.4	4.3	4.5	4.7
Solid Waste Disposal	2.7	1.8	1.4	1.3	1.2	1.2	1.1	1.0	1.0	1.1	0.9	0.9	0.9
Incineration	3.7	1.3	1.1	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8
Open Burning													
Solid Waste Total	6.4	3.1	2.5	2.3	2.2	2.1	2.0	1.9	1.9	2.0	1.7	1.7	1.7
Miscellaneous	5.1	4.0	5.0	5.8	6.9	5.8	4.3	7.1	5.7	4.7	4.4	6.5	5.4
Forest Fires	2.1	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Other Burning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. Organic Solvent													
Misc. Total	7.2	4.8	5.7	6.5	7.6	6.4	4.9	7.7	6.3	5.3	5.0	7.1	6.0
Total of All Sources	101.4	84.1	84.4	81.7	79.6	77.4	72.4	74.5	71.8	67.0	63.1	64.1	61.2

TABLE 12

ESTIMATES OF NATIONAL EMISSIONS OF LEAD
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation													
Highway Vehicles	156.0	118.1	108.2	90.8	56.4	43.9	44.4	38.7	32.6	14.5	3.3	2.8	2.4
Off Highway	7.6	4.5	4.2	3.8	3.0	3.0	2.5	2.1	2.1	1.0	0.2	0.2	0.2
Transportation Total	163.6	122.6	112.4	94.6	59.4	46.9	46.9	40.8	34.7	15.5	3.5	3.0	2.6
Stationary Source Fuel Combustion													
Electric Utilities	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Industrial	9.3	9.1	5.9	4.8	3.8	2.7	1.6	0.5	0.4	0.4	0.4	0.4	0.4
Commercial-Institutional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel Combustion Total	9.6	9.3	6.1	4.9	3.9	2.8	1.7	0.6	0.5	0.5	0.5	0.5	0.5
Industrial Processes	23.9	10.3	5.4	5.2	3.6	3.0	2.7	2.4	2.3	2.3	1.9	1.9	2.0
Solid Waste Disposal	6.7	4.8	4.0	4.0	3.7	3.7	3.1	2.6	2.6	2.8	2.7	2.6	2.5
Total of All Sources	203.8	147.0	127.9	108.7	70.6	56.4	54.4	46.4	40.1	21.1	8.6	8.0	7.6

TABLE 13

EMISSIONS OF PARTICULATE (PM/TSP) FROM TRANSPORTATION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Highway Vehicles													
Gasoline-powered													
Passenger cars	610	680	670	620	570	540	560	550	550	540	540	540	550
Light trucks - 1	80	100	90	90	90	90	80	90	90	100	110	120	120
Light trucks - 2	20	30	60	70	70	70	70	70	70	70	70	60	60
Heavy duty vehicles	60	50	60	60	60	60	50	50	50	50	40	40	40
Motorcycles	4	8	8	8	7	5	4	4	4	3	3	4	4
Total - Gasoline	774	868	888	848	797	765	764	764	764	763	763	764	774
Diesel-powered													
Passenger cars	0	1	2	5	9	10	20	20	20	20	20	20	10
Light trucks	0	0	1	1	3	5	5	5	6	4	4	3	4
Heavy duty vehicles	130	180	210	230	250	280	270	250	270	340	310	320	360
Total - Diesel	130	181	213	236	262	295	295	275	296	364	334	343	374
Highway Vehicle Total	904	1,049	1,101	1,084	1,059	1,060	1,059	1,039	1,060	1,127	1,097	1,107	1,148
Aircraft	100	80	70	70	70	70	70	80	80	90	90	80	80
Railroads	60	50	50	60	50	50	50	40	40	40	40	40	40
Vessels	40	30	30	30	30	30	30	30	30	30	30	30	30
Farm Machinery	40	50	70	70	60	60	60	60	60	70	70	70	70
Construction Machinery	10	10	20	20	20	20	20	20	20	20	20	20	20
Industrial Machinery	20	20	30	30	20	20	20	20	20	10	10	10	10
Other Off-highway Vehicles	4	5	5	5	5	5	5	5	5	5	5	5	7
Transportation Total	1,178	1,294	1,376	1,369	1,314	1,315	1,314	1,294	1,315	1,392	1,362	1,362	1,405

TABLE 14

EMISSIONS OF SULFUR OXIDES FROM TRANSPORTATION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Highway Vehicles													
Gasoline-powered													
Passenger cars	120	130	150	150	140	140	150	160	160	160	170	170	180
Light trucks - 1	20	30	30	30	30	30	30	30	40	40	50	50	50
Light trucks - 2	6	9	20	20	20	20	20	20	20	20	20	20	30
Heavy duty vehicles	10	10	10	10	10	10	10	10	10	10	10	10	10
Motorcycles	0	0	1	1	1	0	0	0	0	0	0	0	0
Total - Gasoline	156	179	211	211	201	200	210	220	230	230	250	250	270
Diesel-powered													
Passenger cars	0	0	1	3	5	10	10	10	10	10	10	10	10
Light trucks	0	0	0	1	2	3	3	3	4	2	2	2	1
Heavy duty vehicles	100	140	170	180	200	220	210	200	210	270	250	260	280
Total - Diesel	100	140	171	184	207	233	223	213	224	282	262	272	291
Highway Vehicle Total	256	319	382	395	408	433	433	433	454	512	512	522	561
Aircraft	10	10	10	10	10	10	10	10	10	10	20	20	20
Railroads	130	110	110	120	120	110	110	80	90	80	80	80	80
Vessels	150	140	210	250	270	250	200	180	190	180	180	180	180
Farm Machinery	30	30	40	50	40	40	40	40	40	50	50	50	50
Construction Machinery	10	20	20	20	20	20	20	20	20	20	20	20	20
Industrial Machinery	20	20	30	20	20	20	10	20	20	10	10	10	10
Other Off-highway Vehicles	1	1	1	1	1	1	1	1	1	2	2	2	2
Transportation Total	607	650	803	866	889	884	824	784	825	864	874	884	923

TABLE 15

EMISSIONS OF NITROGEN OXIDES FROM TRANSPORTATION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Highway Vehicles													
Gasoline-powered													
Passenger cars	3,980	4,520	4,550	4,190	3,880	3,670	3,630	3,410	3,280	2,950	2,760	2,600	2,500
Light trucks - 1	510	610	680	660	670	720	650	670	670	690	690	690	650
Light trucks - 2	220	320	520	550	540	590	520	540	510	490	460	420	400
Heavy duty vehicles	500	470	440	400	380	370	320	320	290	290	240	240	250
Motorcycles	4	8	9	10	10	10	10	10	10	10	10	10	10
Total - Gasoline	5,214	5,928	6,199	5,810	5,480	5,360	5,130	4,950	4,760	4,430	4,160	3,960	3,810
Diesel-powered													
Passenger cars	0	1	3	8	10	20	30	30	30	30	30	30	20
Light trucks	0	0	1	2	6	10	10	10	10	10	10	10	10
Heavy duty vehicles	1,130	1,640	2,040	2,180	2,360	2,640	2,420	2,160	2,130	2,555	2,190	2,180	2,300
Total - Diesel	1,130	1,641	2,044	2,190	2,376	2,670	2,460	2,200	2,170	2,595	2,230	2,220	2,330
Highway Vehicle Total	6,344	7,569	8,243	8,000	7,856	8,030	7,590	7,150	6,930	7,025	6,390	6,180	6,140
Aircraft	110	100	110	120	110	110	110	110	120	130	140	130	130
Railroads	640	660	710	750	750	710	660	540	580	540	520	530	550
Vessels	90	120	170	180	150	190	160	170	180	190	200	210	220
Farm Machinery	400	430	540	560	460	480	470	460	500	560	570	540	560
Construction Machinery	180	190	260	230	230	200	200	200	210	250	280	250	280
Industrial Machinery	220	240	260	260	260	240	220	230	240	200	190	190	190
Other Off-highway Vehicles	10	10	10	10	10	10	10	10	10	10	10	10	20
Transportation Total	7,994	9,319	10,303	10,110	9,826	9,970	9,420	8,870	8,770	8,905	8,300	8,040	8,090

TABLE 16

EMISSIONS OF REACTIVE VOLATILE ORGANIC COMPOUNDS FROM TRANSPORTATION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Highway Vehicles													
Gasoline-powered													
Passenger cars	6,770	5,380	4,860	4,400	3,960	3,790	3,820	3,730	3,700	3,510	3,330	3,190	3,030
Light trucks - 1	920	850	870	830	810	880	800	850	850	880	830	840	800
Light trucks - 2	400	440	680	710	670	740	670	720	710	690	640	600	550
Heavy duty vehicles	790	580	530	500	480	490	420	400	430	360	270	260	270
Motorcycles	80	160	170	140	100	70	50	50	50	30	30	30	30
Total - Gasoline	8,960	7,410	7,110	6,580	6,020	5,970	5,760	5,750	5,740	5,470	5,100	4,920	4,680
Diesel-powered	0	0	1	2	3	5	5	6	6	7	6	6	5
Passenger cars	0	0	0	1	2	3	3	2	1	1	1	1	2
Light trucks	100	130	170	180	190	210	190	200	180	200	170	170	170
Heavy duty vehicles													
Total - Diesel	100	130	171	183	195	218	198	208	187	208	177	177	177
Highway Vehicle Total	9,060	7,540	7,281	6,763	6,215	6,188	5,958	5,958	5,927	5,678	5,277	5,097	4,857
Aircraft	250	190	180	180	180	160	160	170	170	190	190	190	190
Railroads	160	160	170	180	180	170	160	130	140	130	130	130	130
Vessels	330	400	430	420	400	430	410	420	510	410	450	470	480
Farm Machinery	250	220	220	220	190	180	180	160	190	210	200	200	190
Construction Machinery	40	30	40	40	40	40	30	30	30	40	50	50	50
Industrial Machinery	120	80	90	80	80	100	90	80	70	60	60	70	70
Other Off-highway Vehicles	110	160	160	160	170	170	170	160	160	160	160	160	160
Transportation Total	10,320	8,780	8,571	8,043	7,455	7,438	7,158	7,108	7,197	6,878	6,517	6,367	6,127

TABLE 17

EMISSIONS OF CARBON MONOXIDE FROM TRANSPORTATION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Highway Vehicles													
Gasoline-powered													
Passenger cars	49,090	41,430	37,840	34,450	31,850	30,160	30,150	29,510	27,790	25,410	23,650	22,530	21,220
Light trucks - 1	5,800	5,730	6,100	5,960	5,810	6,370	5,760	6,190	6,050	6,280	6,060	6,100	5,770
Light trucks - 2	2,070	2,450	4,120	4,340	4,210	4,700	4,220	4,610	4,450	4,330	4,040	3,740	3,540
Heavy duty vehicles	7,810	6,610	6,500	6,170	5,870	5,780	4,910	4,720	4,380	3,750	2,920	2,800	2,730
Motorcycles	260	540	550	490	370	280	200	190	170	130	120	130	120
Total - Gasoline	65,030	56,760	55,110	51,410	48,110	47,290	45,240	45,220	42,840	39,900	36,790	35,300	33,380
Diesel-powered													
Passenger cars	0	0	2	5	8	10	10	20	20	20	20	20	10
Light trucks	0	0	1	1	3	6	6	5	3	4	4	3	4
Heavy duty vehicles	300	390	500	530	610	700	680	650	650	770	670	680	720
Total - Diesel	300	390	503	536	621	716	696	675	673	794	694	703	734
Highway Vehicle Total	65,330	57,150	55,613	51,946	48,731	48,006	45,936	45,895	43,513	40,694	37,484	36,003	34,114
Aircraft	900	880	960	990	990	960	950	980	1,010	1,090	1,080	1,060	1,050
Railroads	250	240	260	270	270	250	240	190	200	190	180	190	190
Vessels	1,150	1,360	1,470	1,420	1,380	1,440	1,390	1,410	1,700	1,400	1,500	1,560	1,620
Farm Machinery	3,570	2,930	2,370	2,240	2,040	1,880	1,780	1,470	1,900	2,120	1,910	1,830	1,630
Construction Machinery	580	370	340	370	460	370	320	260	250	410	450	520	530
Industrial Machinery	1,780	1,060	1,070	820	1,110	1,330	1,190	1,040	900	850	840	880	880
Other Off-highway Vehicles	840	990	1,050	1,080	1,100	1,150	1,130	1,140	1,130	1,150	1,170	1,190	1,200
Transportation Total	74,400	64,980	63,133	59,136	56,081	55,386	52,936	52,385	50,603	47,904	44,614	43,233	41,214

TABLE 18

EMISSIONS OF PARTICULATE (PM/TSP) FROM FUEL COMBUSTION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Coal													
Electric Utilities	2,220	1,420	1,050	860	720	640	490	510	550	390	390	370	350
Industrial	1,300	360	220	250	250	280	220	110	110	120	90	80	80
Commercial-Institutional	40	40	40	30	30	30	40	20	20	20	20	20	20
Residential	80	20	20	10	10	10	20	20	20	20	10	20	20
Coal Total	3,640	1,840	1,330	1,150	1,010	960	770	660	700	550	510	490	470
Fuel Oil													
Electric Utilities	110	120	140	120	100	90	70	60	50	40	50	50	50
Industrial	80	70	80	70	60	50	50	30	40	40	40	40	30
Commercial-Institutional	60	40	40	30	40	30	30	20	20	20	20	20	20
Residential	20	10	10	10	10	10	10	10	10	8	9	10	10
Fuel Oil Total	270	240	270	230	210	180	160	120	120	108	119	120	110
Natural Gas													
Electric Utilities	6	5	5	6	6	6	5	5	5	5	4	5	4
Industrial	20	20	20	20	20	20	20	20	20	20	10	10	20
Commercial-Institutional	3	3	4	4	4	3	4	3	3	3	3	3	4
Residential	7	7	7	7	6	6	6	6	6	6	6	6	6
Natural Gas Total	36	35	36	37	36	35	35	34	34	34	23	24	34
Wood													
Industrial	180	120	130	130	130	120	110	100	100	100	100	100	90
Residential	460	490	730	870	990	1,020	1,110	1,110	1,120	990	1000	1010	960
Wood Total	640	610	860	1,000	1,120	1,140	1,220	1,210	1,220	1,090	1,100	1,110	1,050
Other Fuels													
Industrial	40	40	30	30	30	20	20	20	20	20	20	20	20
Residential	4	3	3	3	2	2	2	2	2	2	2	2	2
Other Fuels Total	44	43	33	33	32	22	22	22	22	22	22	22	22
Fuel Combustion Total	4,630	2,768	2,529	2,450	2,408	2,337	2,207	2,046	2,096	1,804	1,774	1,766	1,686

TABLE 19

EMISSIONS OF SULFUR OXIDES FROM FUEL COMBUSTION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Coal													
Electric Utilities	14,330	15,200	14,070	14,550	14,190	13,550	13,270	13,250	13,890	13,660	13,260	13,150	13,070
Industrial	2,840	1,700	1,500	1,610	1,380	1,560	1,500	1,540	1,640	1,670	1,680	1,540	1,570
Commercial-Institutional	100	130	180	140	100	120	150	160	180	150	150	140	150
Residential	240	70	50	40	40	50	50	60	60	50	50	60	60
Coal Total	17,510	17,100	15,800	16,340	15,710	15,280	14,970	15,010	15,770	15,530	15,140	14,890	14,850
Fuel Oil													
Electric Utilities	1,450	1,370	1,670	1,440	1,300	1,120	950	760	640	540	670	560	520
Industrial	1,140	880	1,100	910	850	680	700	420	480	490	520	560	450
Commercial-Institutional	800	580	560	480	580	440	430	280	280	270	310	340	330
Residential	190	180	190	160	140	130	120	100	120	120	130	130	140
Fuel Oil Total	3,580	3,010	3,520	2,990	2,870	2,370	2,200	1,560	1,520	1,420	1,630	1,590	1,440
Natural Gas													
Electric Utilities	1	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	2	2	2	2	2	2	2	2	2	2	2	2	2
Commercial-Institutional	1	1	1	1	1	1	1	1	1	1	1	1	1
Residential	1	1	1	1	1	1	1	1	1	1	1	1	1
Natural Gas Total	5	5	5	5	5	5	5	5	5	5	5	5	5
Wood													
Industrial	4	4	6	6	5	5	5	6	6	6	6	6	6
Residential	6	6	9	10	12	12	13	13	13	11	11	11	11
Wood Total	10	10	15	16	17	17	18	19	19	17	17	17	17
Other Fuels													
Industrial	160	100	130	130	120	100	80	70	90	70	90	80	90
Residential	20	10	9	9	6	6	5	7	7	7	5	5	6
Other Fuels Total	180	110	139	139	126	106	85	77	97	77	95	85	96
Fuel Combustion Total	21,285	20,235	19,479	19,490	18,728	17,778	17,278	16,671	17,411	17,049	16,887	16,587	16,408

TABLE 20

EMISSIONS OF NITROGEN OXIDES FROM FUEL COMBUSTION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Coal													
Electric Utilities	3,170	3,880	4,470	4,820	5,150	5,250	5,200	5,410	5,710	5,930	5,820	6,070	6,330
Industrial	700	470	420	460	400	460	450	460	520	550	560	550	560
Commercial-Institutional	20	30	40	30	20	30	30	30	30	30	30	30	30
Residential	16	5	4	3	3	3	4	4	4	4	4	4	4
Coal Total	3,906	4,385	4,934	5,313	5,573	5,743	5,684	5,904	6,264	6,514	6,414	6,654	6,924
Fuel Oil													
Electric Utilities	390	590	680	560	440	370	260	250	220	180	240	210	210
Industrial	300	270	350	260	220	190	200	140	140	140	150	150	120
Commercial-Institutional	190	160	170	140	140	110	110	90	90	80	90	90	90
Residential	110	100	110	90	80	70	60	60	60	60	70	70	70
Fuel Oil Total	990	1,120	1,310	1,050	880	740	630	540	510	460	550	520	490
Natural Gas													
Electric Utilities	880	690	680	740	780	770	690	620	660	650	550	600	560
Industrial	2,770	2,570	2,790	2,710	2,240	2,140	2,230	1,950	2,110	1,970	1,900	2,190	2,260
Commercial-Institutional	110	110	120	130	120	110	120	110	110	110	110	100	120
Residential	220	220	220	220	220	210	210	200	210	200	200	200	210
Natural Gas Total	3,980	3,590	3,810	3,800	3,360	3,230	3,250	2,880	3,090	2,930	2,760	3,090	3,150
Wood													
Industrial	90	90	120	120	120	120	110	130	130	120	120	120	120
Residential	40	40	60	70	80	80	90	90	90	80	80	70	70
Wood Total	130	130	180	190	200	200	200	220	220	200	200	190	190
Other Fuels													
Industrial	50	50	60	70	70	60	60	50	70	30	30	30	40
Residential	60	40	40	30	30	30	20	30	30	30	30	30	30
Other Fuels Total	110	90	100	100	100	90	80	80	100	60	60	60	70
Fuel Combustion Total	9,116	9,315	10,334	10,453	10,113	10,003	9,844	9,624	10,184	10,164	9,884	10,514	10,824

TABLE 21

EMISSIONS OF REACTIVE VOLATILE ORGANIC COMPOUNDS FROM FUEL COMBUSTION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Coal													
Electric Utilities	20	20	20	30	30	30	30	30	30	30	30	40	40
Industrial	4	3	2	3	2	3	3	3	3	3	3	3	3
Commercial-Institutional	1	1	2	1	1	1	1	1	2	1	1	1	1
Residential	55	20	10	10	10	10	10	10	10	10	10	10	10
Coal Total	80	44	34	44	43	44	44	44	45	44	44	54	54
Fuel Oil													
Electric Utilities	7	10	10	10	8	6	4	4	4	3	4	4	4
Industrial	4	5	6	4	3	3	3	2	2	2	2	2	2
Commercial-Institutional	4	3	3	2	3	2	2	2	2	2	2	2	2
Residential	4	4	4	4	3	3	2	2	2	2	2	2	3
Fuel Oil Total	19	22	23	20	17	14	11	10	10	9	10	10	11
Natural Gas													
Electric Utilities	5	4	4	4	4	4	4	3	4	4	3	3	3
Industrial	70	60	70	70	50	50	50	50	50	50	50	50	50
Commercial-Institutional	6	6	6	7	6	6	6	6	6	6	6	6	6
Residential	12	12	12	12	11	11	11	10	11	10	10	10	10
Natural Gas Total	93	82	92	93	71	71	71	69	71	70	69	69	69
Wood													
Industrial	50	50	70	70	70	70	70	70	70	70	70	70	70
Residential	350	370	550	640	730	740	800	790	790	700	700	700	690
Wood Total	400	420	620	710	800	810	870	860	860	770	770	770	760
Other Fuels													
Industrial	7	10	10	10	10	9	7	7	8	7	6	6	6
Residential	2	2	2	1	1	1	1	1	1	2	1	1	1
Other Fuels Total	9	12	12	11	11	10	8	8	9	9	7	7	7
Fuel Combustion Total	601	580	781	878	942	949	1,004	991	995	902	900	910	901

TABLE 22

EMISSIONS OF CARBON MONOXIDE FROM FUEL COMBUSTION
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Coal													
Electric Utilities	100	120	140	160	170	180	180	190	200	210	210	210	230
Industrial	90	60	60	60	50	60	60	60	70	70	70	70	70
Commercial-Institutional	10	10	20	20	10	10	20	20	20	20	20	20	20
Residential	500	160	110	100	90	100	110	120	130	110	110	120	120
Coal Total	700	350	330	340	320	350	370	390	420	410	410	420	440
Fuel Oil													
Electric Utilities	40	60	70	60	40	40	30	20	20	20	20	20	20
Industrial	40	40	50	30	30	30	30	20	20	20	20	20	20
Commercial-Institutional	20	20	20	20	20	20	10	10	20	10	10	10	10
Residential	30	30	30	30	20	20	20	20	20	20	20	20	20
Fuel Oil Total	130	150	170	140	110	110	90	70	80	70	70	70	70
Natural Gas													
Electric Utilities	80	70	70	70	80	80	70	60	70	60	50	60	60
Industrial	420	390	420	410	350	330	340	300	320	300	300	330	340
Commercial-Institutional	20	20	20	20	20	20	20	20	20	20	20	20	20
Residential	40	40	40	40	40	40	40	40	40	40	40	40	40
Natural Gas Total	560	520	550	540	490	470	470	420	450	420	410	450	460
Wood													
Industrial	140	150	200	200	200	200	190	210	210	200	200	200	200
Residential	2,920	3,100	4,610	5,500	6,260	6,510	7,080	7,050	7,140	6,330	6,390	6,450	6,380
Wood Total	3,060	3,250	4,810	5,700	6,460	6,710	7,270	7,260	7,350	6,530	6,590	6,650	6,580
Other Fuels													
Industrial	10	20	20	20	20	20	20	20	20	11	10	10	10
Residential	10	10	10	8	6	6	5	6	7	7	7	7	7
Other Fuels Total	20	30	30	28	26	26	25	26	27	18	17	17	17
Fuel Combustion Total	4,470	4,300	5,890	6,748	7,406	7,666	8,225	8,166	8,327	7,448	7,497	7,607	7,567

TABLE 23

EMISSIONS OF PARTICULATE (PM/TSP) FROM INDUSTRIAL PROCESSES
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Cattle Feed Lots (0211)	20	20	20	20	20	20	20	20	20	20	20	20	20
Cotton Ginning (0724)	20	20	20	20	20	30	20	10	20	20	20	30	30
Metallic Ore Mining (10)	530	320	210	210	180	200	110	110	130	130	110	130	130
Coal Mining (1211)	350	250	250	290	310	310	320	300	350	310	310	310	320
Crushed Stone (142)	1,350	760	610	570	450	380	340	370	400	420	480	480	510
Sand and Gravel(144)	50	40	50	50	40	40	30	30	40	40	50	50	40
Clays (145)	1,610	290	210	150	130	70	60	70	80	80	60	60	60
Potash/Phosphate Rock (1474,1475)	40	30	30	30	30	10	10	10	10	10	10	5	6
Feed and Grain Milling (204)	70	60	40	50	40	50	50	30	50	50	60	40	40
Lumber and Plywood (24)	80	70	90	80	70	70	60	70	80	80	90	100	100
Pulp Mills (261,262)	620	220	130	120	140	90	100	100	120	120	100	100	80
Chemicals (28)	220	120	140	140	140	120	100	110	130	120	90	100	100
Petroleum Refining (2911)	60	70	60	50	50	40	40	30	30	20	20	20	20
Asphalt Paving and Roofing (295)	560	320	120	130	110	90	90	110	140	120	120	130	130
Glass (321,322)	40	40	30	30	30	30	30	30	30	30	20	20	20
Cement (3241)	1,580	640	620	520	380	290	220	240	270	270	210	200	200
Brick and Tile (3251)	40	30	20	20	10	10	7	10	10	10	10	10	10
Concrete, Lime, Gypsum (327)	580	290	150	140	130	100	80	80	90	90	90	90	90
Clay Sintering (3295)	100	40	10	10	10	10	10	10	10	10	10	10	10
Iron and Steel (3312)	1,190	570	450	400	310	300	200	180	180	160	130	140	160
Ferroalloys (3313)	160	90	60	40	30	30	20	20	20	20	20	20	20
Iron and Steel Foundries (332)	150	70	70	60	50	40	40	30	30	40	40	40	40
Primary Nonferrous Smelters (333)	390	200	100	100	90	90	60	70	70	60	50	50	60
Secondary Nonferrous Smelters (334,336)	60	50	40	50	40	40	30	30	40	40	30	30	30
Grain Elevators (4421,5153)	670	590	500	550	490	550	510	280	430	490	390	350	350
Total	10,540	5,200	4,030	3,830	3,300	3,010	2,557	2,350	2,780	2,760	2,540	2,535	2,576

TABLE 24

EMISSIONS OF SULFUR OXIDES FROM INDUSTRIAL PROCESSES
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Natural Gas Production (1311)	100	160	130	140	140	150	140	170	150	150	150	170	170
Pulp Mills (261,262)	150	150	180	180	200	200	200	210	220	220	230	250	250
Sulfuric Acid (2819)	540	330	260	250	250	220	170	180	190	190	170	170	170
Carbon Black (2895)	0	10	10	10	10	10	10	10	10	10	10	10	10
Petroleum Refining(2911)	700	830	900	880	840	770	740	740	740	750	880	870	900
Glass (321,322)	20	30	30	30	30	30	30	30	30	30	30	20	30
Cement (3241)	560	460	630	630	570	550	480	520	560	560	550	540	570
Lime (3274)	30	30	30	30	30	30	20	20	30	20	20	20	20
Iron and Steel (3312)	650	620	550	580	510	480	320	290	350	370	290	320	360
Primary Copper (3331)	3,180	2,140	1,370	1,450	990	1,270	970	890	810	600	530	530	560
Primary Lead and Zinc (3332,3333)	410	110	100	120	70	70	160	110	110	220	190	180	210
Primary Aluminum (3334)	70	60	80	80	90	80	60	60	80	60	60	60	70
Secondary Lead (3341)	20	20	30	40	30	30	30	20	20	20	20	30	30
Total	6,430	4,950	4,300	4,420	3,760	3,890	3,330	3,250	3,300	3,200	3,130	3,170	3,350

TABLE 25

EMISSIONS OF NITROGEN OXIDES FROM INDUSTRIAL PROCESSES
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Pulp Mills (261,262)	20	20	20	20	20	20	20	20	20	20	20	30	30
Organic Chemicals (286)	60	60	60	70	50	50	40	50	50	50	60	60	60
Ammonia (2873)	30	40	40	50	50	50	40	30	40	40	30	40	40
Nitric Acid (2873)	150	110	100	100	100	90	60	50	50	40	30	30	30
Petroleum Refining (2911)	220	240	260	250	240	210	200	200	200	200	220	210	220
Glass (321,322)	40	50	60	60	50	60	50	50	50	50	50	50	50
Cement (3241)	90	80	100	100	90	80	70	80	90	90	90	90	90
Lime (3274)	20	20	20	20	20	20	20	20	20	20	20	20	20
Iron and Steel (3312)	70	70	80	70	60	60	40	40	50	50	40	40	50
Total	700	690	740	740	680	640	540	540	570	560	560	570	590

TABLE 26

EMISSIONS OF REACTIVE VOLATILE ORGANIC COMPOUNDS FROM INDUSTRIAL PROCESSES
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Crude Oil Production, Storage and Transfer (1311,4463)	550	530	570	570	560	540	530	530	550	540	530	530	540
Food and Beverages (20)	190	170	180	180	170	180	180	180	160	170	160	160	170
Textiles (22)	10	20	20	20	20	20	20	10	20	20	10	10	10
Graphic Arts (27)	290	250	350	350	340	260	240	270	360	330	220	190	230
Plastics (2821,3079)	360	320	440	460	430	360	330	390	480	450	370	280	380
Organic Chemicals (286)	570	700	880	900	830	790	670	800	870	860	890	940	1,010
Other Chemicals (28)	620	500	610	630	570	590	510	550	550	510	510	560	570
Petroleum Refining(2911)	720	880	970	970	970	960	900	810	780	720	690	690	690
Rubber Tires (3011)	50	50	60	50	40	50	40	50	50	50	50	50	50
Iron and Steel (3312)	360	300	270	290	250	230	150	140	170	150	140	150	170
Petroleum Product Storage and Transfer (5171,5541)	1,580	1,760	1,850	1,700	1,540	1,490	1,430	1,400	1,400	1,420	1,460	1,520	1,530
Dry Cleaning (721)	240	230	290	290	290	240	210	220	250	220	160	170	210
Adhesives	50	40	60	60	50	40	40	40	60	50	40	30	40
Degreasing	640	450	550	560	510	420	360	410	500	490	340	390	370
Solvent Extraction Processes	40	30	50	40	40	40	30	40	40	40	40	40	40
Surface Coating	2,390	1,880	2,510	2,500	2,320	1,820	1,560	1,770	2,250	2,220	2,200	2,300	2,240
Other Organic Solvent Use	270	220	280	300	290	300	260	260	300	280	250	290	280
Total	8,930	8,330	9,940	9,870	9,220	8,330	7,460	7,870	8,790	8,520	8,060	8,300	8,530

TABLE 27

EMISSIONS OF CARBON MONOXIDE FROM INDUSTRIAL PROCESSES
(GIGAGRAMS/YEAR)

Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Pulp Mills (261,262)	550	550	650	660	720	720	700	760	800	790	850	870	870
Inorganic Pigments (2816)	20	20	30	30	30	30	30	30	30	40	40	40	40
Charcoal (2861)	50	30	40	50	40	40	30	30	40	40	40	40	40
Organic Chemicals (286)	310	410	490	510	450	470	420	470	510	520	520	560	610
Ammonia (2873)	100	120	120	130	140	140	110	100	120	120	100	120	120
Carbon Black (2895)	2,600	1,420	1,630	1,590	1,290	1,320	950	1,030	1,190	1,060	1,060	1,100	1,070
Petroleum Refining (2911)	2,000	2,040	1,780	1,690	1,600	1,110	700	470	380	370	350	340	340
Asphalt Roofing (2952)	10	10	20	20	10	10	10	10	20	20	20	20	20
Lime (3274)	10	10	20	20	10	10	10	10	10	10	10	10	10
Iron and Steel (3312)	1,620	1,100	1,210	1,200	970	990	640	670	720	670	620	680	730
Iron Foundries (3321)	1,090	590	440	410	310	290	200	200	180	180	150	150	160
Primary Aluminum (3334)	590	580	720	750	760	740	540	550	670	570	500	550	660
Total	8,950	6,880	7,150	7,060	6,330	5,870	4,340	4,330	4,670	4,390	4,260	4,480	4,670

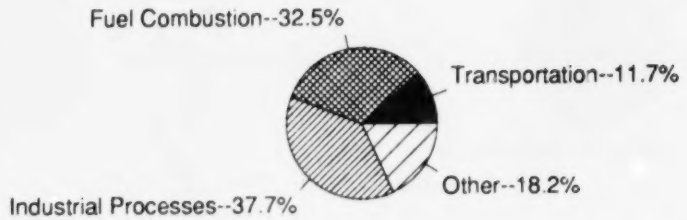
TABLE 28

EMISSIONS OF LEAD FROM INDUSTRIAL PROCESSES
(GIGAGRAMS/YEAR)

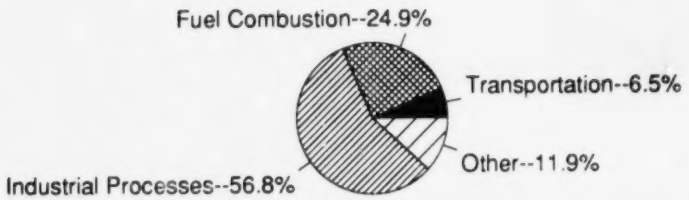
Source Category	1970	1975	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Iron and Steel Industry	3,087	1,073	911	769	476	468	335	219	223	212	200	130	160
Primary Nonferrous Metals	12,350	5,569	1,463	1,316	1,038	859	874	871	679	828	640	640	660
Secondary Nonferrous Metals	5,612	1,905	1,440	1,391	1,020	883	784	694	784	796	770	820	890
Mineral Products	764	440	378	296	272	254	202	173	160	167	120	120	120
Miscellaneous	2,050	1,338	1,227	1,389	778	585	515	485	453	291	200	210	180
Total	23,863	10,325	5,419	5,161	3,584	3,049	2,710	2,442	2,299	2,294	1,930	1,920	2,010

Figure 7

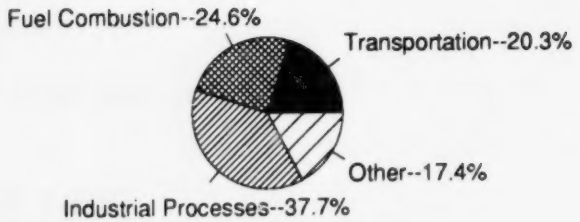
Emissions of Particulate (PM/TSP) by Source Category 1940, 1970 and 1988



Particulate Emissions - 1940



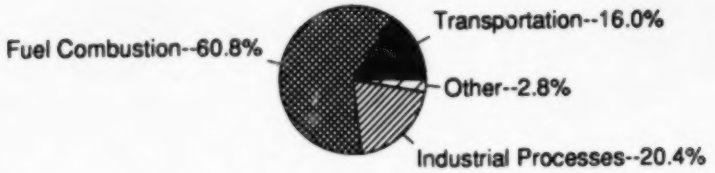
Particulate Emissions - 1970



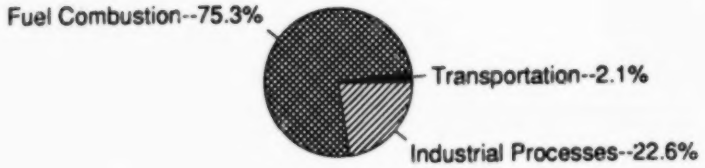
Particulate Emissions - 1988

Figure 8

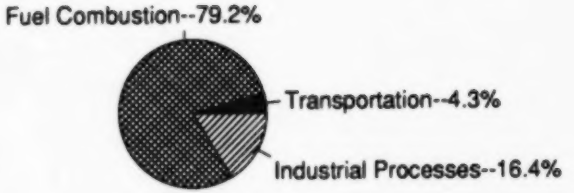
Emissions of Sulfur Oxides by Source Category, 1940, 1970 and 1988



Sulfur Oxide Emissions - 1940



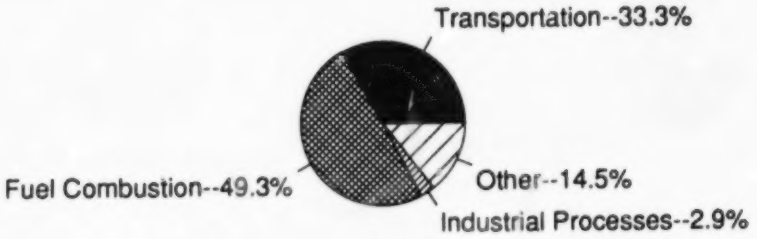
Sulfur Oxide Emissions - 1970



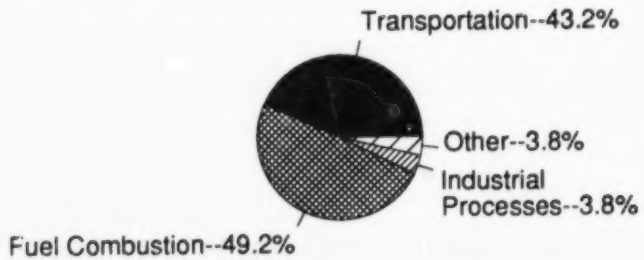
Sulfur Oxide Emissions - 1988

Figure 9

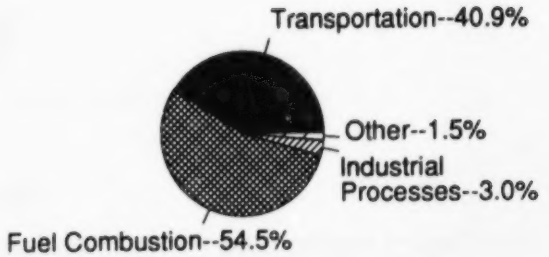
Emissions of Nitrogen Oxides by Source Category, 1940, 1970 and 1988



Nitrogen Oxide Emissions - 1940



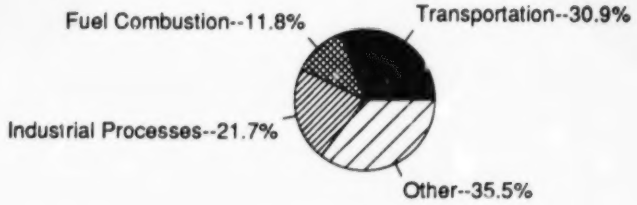
Nitrogen Oxide Emissions - 1970



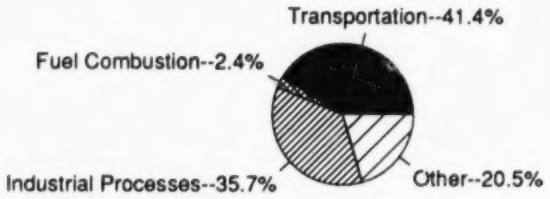
Nitrogen Oxide Emissions - 1988

Figure 10

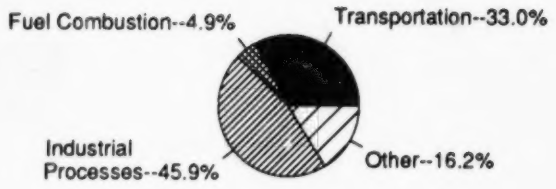
Emissions of Reactive Volatile Organic Compounds (VOCs) by Source Category, 1940, 1970 and 1988



Reactive VOC Emissions - 1940



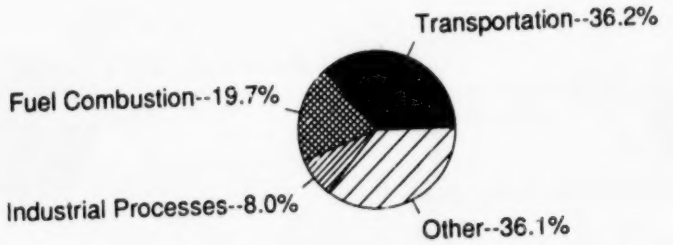
Reactive VOC Emissions - 1970



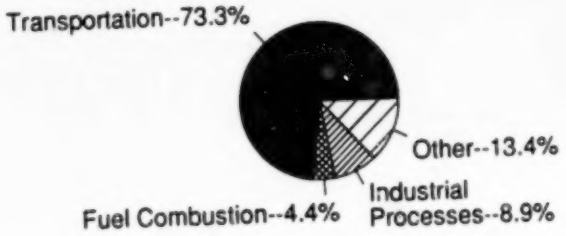
Reactive VOC Emissions - 1988

Figure 11

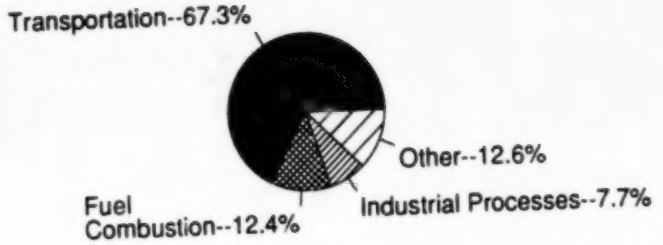
Emissions of Carbon Monoxide by Source Category, 1940, 1970 and 1988



Carbon Monoxide Emissions - 1940



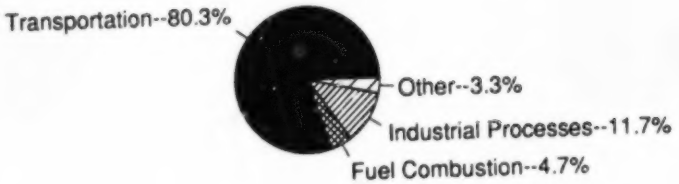
Carbon Monoxide Emissions - 1970



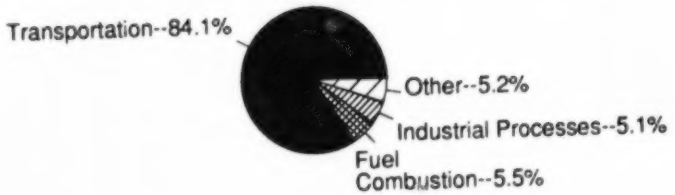
Carbon Monoxide Emissions - 1988

Figure 12

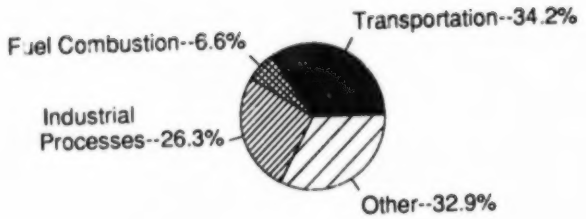
Emissions of Lead by Source Category, 1970, 1980 and 1988



Lead Emissions - 1970



Lead Emissions - 1980



Lead Emissions - 1988

3. METHODS

The preparation of an emission inventory involves many steps to achieve the desired result, which is to estimate the amount of emissions for selected pollutants in a defined geographical area over a specific period of time. Ideally, nationwide emission estimates should result from a summation of county, State, and Regional data in which each component is reported separately. The National Emissions Data System (NEDS) uses this procedure. The methods used to prepare data for this publication are as similar as possible to those used for NEDS data preparation. To develop the NEDS point source file, a complex calculation procedure must be used which includes data from (1) state-by-state emissions calculation, (2) reporting of emissions for individual sources and (3) summation of these individual emissions totals to produce national totals. Because point source data is compiled from this variety of sources, there is a much greater chance for errors or omissions to occur in the NEDS data.

In addition to the NEDS point source file, there is a NEDS area source file. The NEDS area source file contains estimates of emissions from sources not included in the NEDS point source file. The sources covered by the NEDS area source file include the following: small (< 100 T/Y) combustion sources, transportation, and other miscellaneous categories. Because of the basic similarity of techniques, discrepancies between national totals reported herein and those given in NEDS reports are due largely to incomplete data reporting and errors in the NEDS data. An additional difference between the detailed NEDS reports and this publication is that the NEDS reports include some fugitive dust categories not covered by this report.

Fugitive particulate emissions (emissions from unconfined sources such as storage piles, material loading, etc.) are incompletely accounted for in the emission totals. Rough estimates of industrial process fugitive emissions are included for some industries. Area source fugitive dust emissions (unpaved roads, construction activities, etc.) are not included at all. Similarly, natural sources of particulate, such as wind erosion or dust, are not included. (An exception to the previous statement is forest fires, some of which result from natural causes). In total, these fugitive emissions may amount to a considerable portion of total particulate emissions. The controls applied to these sources have, to date, been minimal. Due to the lack of adequate emission factors and emission inventory techniques for these sources, fugitive particulate emissions have not been included in most emission inventories. As additional data become available, it is expected that estimates of fugitive particulate emissions will be included in future emission inventories. It should be noted, however, that a major portion of the fugitive particulate emissions are relatively large particles that are not readily captured by particulate air quality monitors. Similarly, these large particles do not effectively enter into the human respiratory system. The quality of NEDS data over time has improved so that the differences between NEDS emission reports for 1977 and later years and national emission totals determined by the procedure used for this publication are not as great as in earlier NEDS reports. Moreover, historical NEDS data are not revised to account for updated emission factors, errors or omissions in the data. As a result, annual NEDS publications do not represent a consistent trend in estimated emissions.

Because it is impossible to test every pollutant source individually, particularly area sources, an estimating procedure must be used. In order to do this, however, one must either estimate the emissions directly or estimate the magnitude of other variables that can then be related to emissions. These indicators include fuel consumption, vehicle miles, population, sales, tons of refuse burned, raw materials processed, etc., which are then multiplied by appropriate emission factors to obtain emission estimates. The limitations and applicability of emission factors should be noted. In general, emission factors are not precise indicators of emissions from a single source; rather, they are quantitative estimates of the average rate of pollutants released as a result of some activity. They are most valid when applied to a large number of sources and processes. If their limitations are

recognized, emission factors are extremely useful in estimating emission levels. A detailed discussion of emission factors and related information is contained in Reference 2. The emission factor thus relates quantity of pollutants emitted to indicators such as those noted above, and is a practical approach for estimating emissions from various source categories.

A basic discussion of trends is meaningful only when there is a common basis for evaluation. It was necessary, therefore, to quantify emissions using the same criteria for each year. This meant using the same estimation techniques, using equal or equivalent data sources, covering the same pollutant sources, and using compatible estimates of pollutant control levels from year to year. Estimates for previous years were updated using current emission factors and including the most recent information available. The criteria used in calculating emissions was the same for all years.

The methodology used in generation of emission estimates for individual source categories follows.

3.1 Transportation

3.1.1 Motor Vehicles

Emission estimates from gasoline and diesel-powered motor vehicles were based upon vehicle-mile tabulations and emission factors. Eight vehicle categories are considered; light duty gasoline (mostly passenger cars), light duty diesel passenger cars, light duty gasoline trucks (trucks less than 6000 pounds in weight), light duty gasoline trucks 6000 to 8500 pounds in weight, light duty diesel trucks, heavy duty gasoline trucks and buses, and heavy duty diesel trucks and buses, and motorcycles. The emission factors used are based on the latest available data from Reference 3. The MOBILE 4 model, developed by the EPA Office of Mobile Sources was used to calculate emission factors for each year. The emission factors are weighted to consider the approximate amount of motor vehicle travel in low altitude areas, high altitude areas, and California to obtain overall national average emission factors. For each area a representative average annual temperature, together with national averages for motor vehicle model year distributions and hot/cold start vehicle operation percentages were used to calculate the emission factors. Average speed is taken into account according to the published distribution of vehicle-miles travelled (VMT) as published in Reference 4. The published VMT are divided into three road categories corresponding to roads with assumed average speeds of 55 miles per hour for interstates and other primary highways, 45 miles per hour for other rural roads, and 19.6 miles per hour for other urban streets. For 1940 and 1950, average speeds were assumed to be 45, 35 and 19.6 miles per hour for these roadway classifications.

Lead emission estimates from gasoline-powered-motor vehicles, were based on highway gasoline consumption, lead content of gasoline, percent unleaded gasoline, and emission factors. The gasoline consumption is based on highway gasoline usage as published in Reference 4. The lead content of gasoline was obtained from Reference 13 for 1970 and Reference 2 for 1975-88. The percent unleaded gasoline is obtained from Reference 6. The emission factor was also obtained from Reference 2.

3.1.2 Aircraft

Aircraft emissions are based on emission factors and aircraft activity statistics reported by the Federal Aviation Administration.[5] Emissions are based on the number of landing-takeoff (LTO) cycles. Any emissions in cruise mode, which is defined to be above 3000

feet (1000 meters) are ignored. Average emission factors for each year, which take into account the national mix of aircraft types for general aviation, military, and commercial aircraft, are used to compute the emissions.

3.1.3 Railroads

The Department of Energy reports consumption of diesel fuel and residual fuel oil by railroads.[34] Average emission factors applicable to diesel fuel consumption were used to calculate emissions. The average sulfur content of each fuel was used to estimate SO_x emissions. Coal consumption by railroads was obtained from References 7 and 13.

3.1.4 Vessels

Vessel use of diesel fuel, residual oil, and coal is reported by the Department of Energy.[34,7] Gasoline use is based on national boat and motor registrations, coupled with a use factor (gallons/motor/year) from Reference 8 and marine gasoline sales as reported in Reference 4. Emission factors from AP-42[2] are used to compute emissions. Since AP-42 does not contain an emission factor for coal use by vessels, an average emission factor for coal combustion in boilers was used.

3.1.5 Non-highway Use of Motor Fuels

Gasoline and diesel fuel are also consumed by off-highway vehicles. The fuel use is divided into seven categories; farm tractors, other farm machinery, construction equipment, industrial machinery, small general utility engines such as lawn mowers and snowthrowers, snowmobiles, and motorcycles. Fuel use is estimated for each category from estimated equipment population and an annual use factor of gallons/unit/year[8], together with reported off-highway diesel fuel deliveries given in Reference 34 and off-highway gasoline sales reported in Reference 4.

3.2 Fuel Combustion in Stationary Sources

3.2.1 Coal

Bituminous coal, lignite, and anthracite coal use is reported by the Department of Energy.[7,31] Most coal is consumed by electric utilities. Average emission factors and the sulfur content of each type of coal were used to estimate emissions. The degree of particulate control was based on a report by Midwest Research Institute[9] together with data from NEDS[10]. Sulfur content data for electric utilities are available from the Department of Energy[11]. Sulfur contents for other categories are based on coal shipments data reported in Reference 7 and average sulfur contents of coal shipped from each production district as reported in Reference 13 or 24. For electric utilities, SO_2 emissions are adjusted to account for flue gas desulfurization controls, based on data reported in Reference 25.

3.2.2 Fuel Oil

Distillate oil, residual oil, and kerosene are consumed by stationary sources nationwide. Consumption by user category is reported by the Department of Energy.[34] Average emission factors and the sulfur content of each fuel were used to estimate emissions.

3.2.3 Natural Gas

Natural gas consumption data are reported by the Department of Energy.[12] Average emission factors from AP-42 were used to calculate the emission estimates.

3.2.4 Other Fuels

Consumption of wood has been estimated by the Department of Energy.[27,35] Consumption of bagasse is based on data reported in NEDS.[10] Sales of liquified petroleum gas (LPG) are reported in Reference 6. Estimated consumption of coke and coke-oven gas are based on References 11 and 26. Average emission factors from NEDS were used to calculate emissions.

Lead emissions from the combustion of waste oil were based on information obtained from Reference 32. The amount of waste oil burned has been assumed to remain constant and the emissions have been changed as a result of a decrease in the lead content of the waste oil.

3.3 Industrial Processes

In addition to fuel combustion, certain other industrial processes generate and emit varying quantities of pollutants into the air. The lack of published national data on production, type of equipment, and controls, as well as an absence of emission factors, makes it impossible to include estimates of emissions from all industrial process sources.

Production data for industries that produce the great majority of emissions were obtained from publicly available reports. Generally, the Minerals Yearbook,[13] published by the Bureau of Mines, and Current Industrial Reports,[14] published by the Bureau of the Census, provide adequate data for most industries. Average emission factors were applied to production data to obtain emissions. Control efficiencies applicable to various processes were estimated on the basis of published reports[9] and from NEDS data.[10]

For the purposes of this report, petroleum product storage and marketing operations (gasoline, crude oil, and distillate fuel oil storage and transfer, gasoline bulk terminals and bulk plants, retail gasoline service stations) are included as industrial processes. Also included as industrial processes are industrial surface coating and degreasing operations, graphic arts (printing and publishing), and dry cleaning operations. All of these processes involve the use of organic solvents. Emissions from the consumption of organic solvents are estimated based on data reported in Reference 15. It is assumed that all solvents consumed are eventually released as air pollution, except for industrial surface coating operations. Estimates of the level of control for surface coating operations have been derived from References 10 and 28. In addition, the methodology given in Reference 15 has been updated to be consistent with similar procedures used for estimating organic solvent emissions in the National Emissions Data System (NEDS).[29]

3.3.1 Miscellaneous Industrial Processes for Lead

Lead emissions from miscellaneous industrial processes include the major source of lead alkyl production as well as other minor sources such as type metal production, can soldering, cable covering, and other minor sources. The lead alkyl production is based on information from Reference 33. The production information for the other minor sources is from Reference 13.

3.4 Solid Waste Disposal

A study conducted in 1968 on solid waste collection and disposal practices[16] was the basis for estimating emissions from solid waste disposal. Results of this study indicate that the average collection rate of solid waste is about 5.5 pounds per capita per day in the United States. It has been stated that a conservative estimate of the total generation rate is 10 pounds per capita per day. The results of this survey were updated based on data reported in NEDS and used to estimate, by disposal method, the quantities of solid waste generated. Average emission factors were applied to these totals to obtain estimates of total emissions from the disposal of solid wastes.

3.5 Miscellaneous Sources

3.5.1 Forest Fires

The Forest Service of the Department of Agriculture publishes information on the number of forest fires and the acreage burned.[17] Estimates of the amount of material burned per acre are made to estimate the total amount of material burned. Similar estimates are made to account for managed burning of forest areas. Average emission factors were applied to the quantities of materials burned to calculate emissions.

3.5.2 Agricultural Burning

A study[18] was conducted by EPA to obtain from local agricultural and pollution control agencies estimates of the number of acres and estimated quantity of material burned per acre in agricultural burning operations. These data have been updated and used to estimate agricultural burning emissions, based on average emission factors.

3.5.3 Coal Refuse Burning

Estimates of the number of burning coal-refuse piles existing in the United States are made in reports by the Bureau of Mines.[19] Their publication presents a detailed discussion of the nature, origin, and extent of this source of pollution. Rough estimates of the quantity of emissions were obtained using this information by applying average emission factors for coal combustion. It was assumed that the number of burning refuse piles decreased to a negligible amount by 1975.

3.5.4 Structural Fires

The United States Department of Commerce publishes information on the number and types of structures damaged by fire in their statistical abstracts.[20] Emissions were estimated by applying average emission factors for wood combustion to these totals.

3.5.5 Non-industrial Organic Solvent Use

This category includes non-industrial sales of surface coatings (primarily for architectural coating, solvent evaporation from consumer products (aerosols, space deodorants, polishes, toiletries, etc.), use of volatile organic compounds as general cleaning solvents, paint removers, and liquefaction of asphalt paving compounds, and other undefined end uses. Total national organic solvent use is estimated from chemical production reports of References 21 and 33, together with estimates of the portion of total production for use as solvent for each chemical.[15,29] It is assumed that all solvent production is equal to the amount necessary to make up for solvent lost through evaporation.

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4. ANALYSIS OF TRENDS

National trends in air pollutant emissions are a function of a number of factors. Air pollution control measures and economic conditions have the strongest impact on total emissions. National emission trends do not provide any insight into the distribution or concentration of air pollution sources within the United States. Therefore, local emission trends do not necessarily coincide with national emission trends. Based on the national implementation of control measures for some classes of sources, such as highway motor vehicles, it is reasonable to infer that for most localities, the national trend in emissions reasonably approximates local trends in emissions for the same class of sources.

In addition to the fact that national emission trends do not measure local changes in emission densities, national emission trends may not be consistent with air quality trends because of the impact of meteorological factors on air quality data. Also, the estimates for PM, SO_x, and NO_x emissions include more substances than are routinely measured by ambient air monitoring equipment. For example, high-volume air samplers collect only suspended particulate approximately 0.3 to 100 micro-meters in diameter, but particulate emission inventories include both suspended and settled particulate generated by man's activities. Likewise, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) ambient air monitors measure only those two compounds while oxides of sulfur (SO_x) and nitrogen (NO_x) are included in the emission estimates. In each case, the substance measured by the ambient air monitor is the most prevalent constituent of its pollutant class or is acknowledged to be its most representative indicator. In this report, emissions of sulfur oxides are reported as the equivalent weight of SO_2, which is the predominant sulfur oxide species. Some emissions of sulfur trioxide (SO_3) are also included, expressed at the equivalent weight of SO_2. Similarly, nitrogen oxides include predominantly nitric oxide (NO) and nitrogen dioxide (NO_2). Other nitrogen oxides are probably emitted in small amounts. In this report all nitrogen oxide emissions are expressed as the equivalent weight of NO_2. Estimates of oxidant emissions are not provided because most oxidant species are secondary pollutants generated by photochemical reactions in the atmosphere. Emission estimates of VOC, a major ingredient in oxidant-producing reactions, were developed from current emission factors.[2,3] Generally excluded from VOC estimates were emissions of methane, ethane, methyl chloroform, and other compounds which are considered to be of negligible photochemical reactivity. Organic species were identified based on Reference 22. If no data were available for a source category, the total non-methane hydrocarbon or the total hydrocarbon emission factor from Reference 2 was used. Highway vehicle emissions were estimated as non-methane VOC's.[3]

The following sections discuss the most important factors influencing the emission trends for each pollutant.

4.1 Particulate (PM/TSP)

1940-1970

The estimated particulate emissions for 1940, 1950 and 1960 are 10 to 30 percent higher than in 1970. Even though industrial production levels and the quantities of fuels consumed were lower than the post-1970 period, the general lack of air pollution controls before 1970 resulted in relatively large particulate emissions. Also, for the years 1940 and 1950, particulate emissions from coal combustion by railroads and from forest wildfires were significant.

A large portion of the particulate emissions from stationary source fuel combustion, result from the combustion of coal. In 1940, coal was consumed largely in the industrial and residential sectors. Residential coal use has declined substantially since 1940, resulting in a corresponding reduction in emissions. Industrial coal use has also declined, but not to the same extent. The degree of control employed by industrial coal consumers has increased, however, so that overall industrial coal combustion emissions decreased by 1970 to only about 40 percent of the estimated

1940 level. On the other hand, coal combustion by electric utilities has increased greatly, from an estimated 51 million tons in 1940 to 321 million tons in 1970. This increased consumption resulted in increased emissions from 1940 to 1950. Since then, particulate emissions from electric utilities have decreased, despite continued increases in coal consumption. Installation of improved control equipment is responsible for this reduction.

Particulate emissions from industrial processes increased from 1940 to 1950, reflecting increased industrial production. From 1950 to 1970, industrial output continued to grow, but installation of pollution control equipment helped to offset the increase in industrial production. As a result, from 1950 to 1960 industrial process emissions stayed about the same, and decreased slightly from 1960 to 1970.

1970-1988

Since 1970, particulate emissions have decreased substantially as the result of air pollution control efforts. The extent of the reduction is most evident from the data in Table 29 which shows theoretical 1988 national emission estimates, assuming that pollutant control levels did not change since 1970. Figure 13 illustrates this difference. Overall, particulate emissions would have increased by about 20 percent from 1970 to 1988 with no change in the degree of control from 1970. In reality, as shown in Table 1, particulate emissions decreased about 63 percent from 1970 to 1988. Thus, 1988's actual particulate emissions were about a third of what they might have been without the additional control put in place since 1970.

A large portion of the particulate emissions from stationary source fuel combustion result from the combustion of coal. In 1970, a larger portion of coal was consumed in the industrial and residential sectors. Residential coal use has declined substantially since 1970, resulting in a corresponding reduction in emissions. Industrial coal use has declined, but not to the same extent. The degree of control employed by industrial coal consumers has increased, however, so that overall industrial coal combustion emissions have decreased by 1988 to only about 7 percent of the estimated 1970 level. On the other hand, coal combustion by electric utilities has increased greatly, from an estimated 321 million tons in 1970 to 757.6 million tons in 1988. However, particulate emissions from electric utilities have decreased, despite continued increases in coal consumption. Installation of improved control equipment is responsible for this reduction. New facilities constructed in the 1970's were required to meet New Source Performance Standards (NSPS) requirements to achieve a high degree of control. From Tables 2 and 29, it can be seen that if the 1970 level of control had remained in effect in 1988, electric utility emissions would have more than doubled, from 2.3 teragrams to 5.3 teragrams. Estimated actual 1988 emissions from electric utilities were 0.4 teragrams, a decrease of 83 percent from 1970.

Particulate emissions from industrial processes have been reduced substantially due to installation of improved control equipment mandated by air pollution control programs. Since 1970, actual emissions from industrial processes declined by 75 percent. Table 23 shows estimated emissions for specific processes. These annual emissions estimates reflect changes in production levels along with an increase in average control levels from 1970 to 1988.

TABLE 29

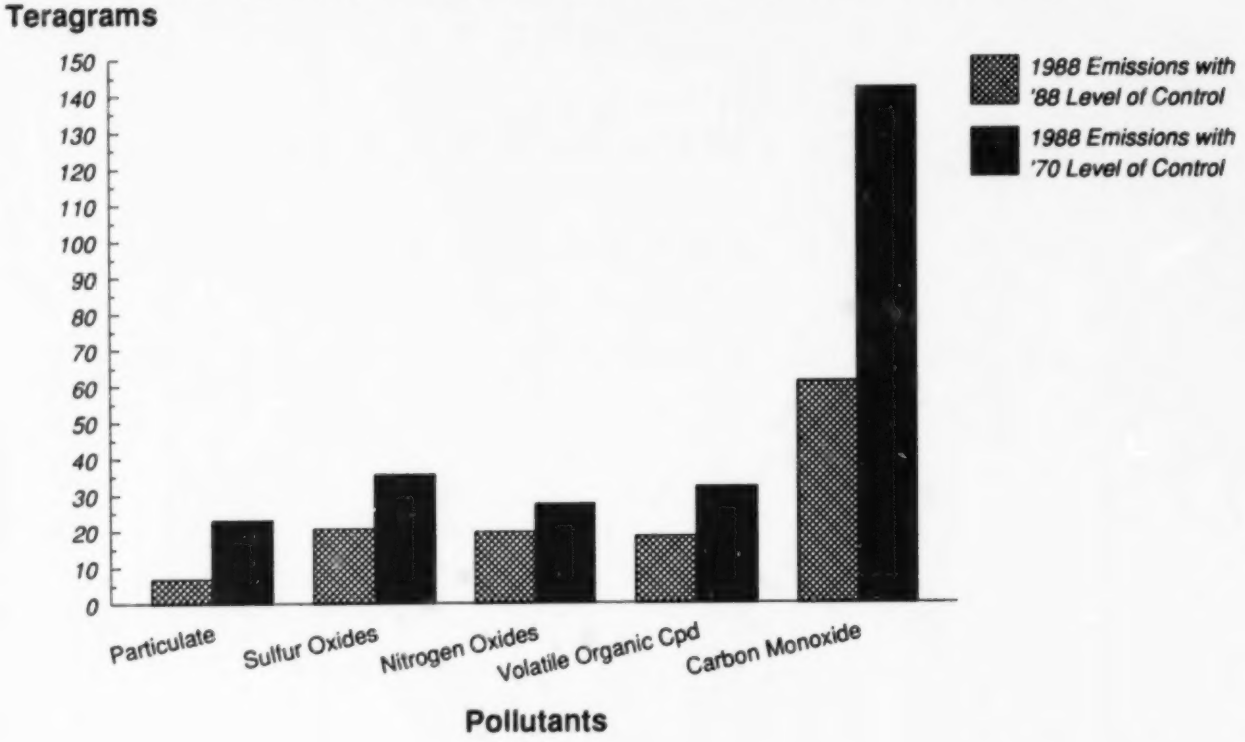
1988 NATIONAL EMISSION ESTIMATES
WITH 1970 LEVEL OF CONTROL
(TERAGRAMS/YEAR)

Source Category	PM	SO2	NOX	VOC	CO	Pb*
Transportation						
Highway Vehicles	1.7	0.6	12.4	15.5	105.2	200.1
Non-Highway	0.2	0.3	1.9	1.3	7.2	4.7
Transportation Total	1.9	0.9	14.3	16.8	112.4	204.8
Stationary Source Fuel Combustion						
Electric Utilities	5.3	25.4	8.3	0.0	0.3	0.6
Industrial	1.4	2.4	3.1	0.1	0.6	9.2
Residential/Commercial	1.1	0.7	0.6	0.7	6.6	0.0
Fuel Combustion Total	7.8	28.5	12.0	0.8	7.5	9.8
Industrial Processes (SIC)						
Mining Operations (10,12,13,14)	4.3	0.4	0.0	0.0	0.0	0.2
Food and Agriculture (02,07,20)	1.3	0.0	0.0	0.2	0.0	0.0
Wood Products (24,26)	1.1	0.3	0.0	0.0	0.9	0.0
Chemicals (28)	0.3	0.8	0.3	2.1	2.9	0.1
Petroleum Refining (29)	0.7	1.2	0.2	0.9	2.3	0.0
Mineral Products (32)	2.4	0.6	0.2	0.0	0.0	0.4
Metals (33)	1.2	2.8	0.0	0.2	2.7	14.9
Miscellaneous	0.0	0.0	0.0	6.8	0.0	0.1
Industrial Processes Total	11.3	6.1	0.7	10.2	8.8	15.7
Solid Waste	1.2	0.1	0.3	2.0	7.3	2.8
Miscellaneous	0.9	0.0	0.2	2.4	6.0	0.0
Total	23.1	35.6	27.5	32.2	142.0	233.1
1988 Actual Emissions (Table 1)	6.9	20.7	19.8	18.6	61.2	7.6
Theoretical 1988 Emissions As a Percentage of 1988 Actual Emissions	336.4	172.1	138.9	173.5	232.2	3,063.1
1970 Actual Emissions (Table 1)	18.5	28.3	18.5	25.0	101.4	203.8
Theoretical 1988 Emissions As A Percentage of 1970 Actual Emissions	124.5	125.7	148.6	129.1	140.0	114.4

*Pb emissions are expressed in gigagrams/year.

Figure 13

Theoretical Estimates of 1988 National Emissions of TSP, SOX, NOX, VOC, and CO with '70 Control



Comments on Particulate Emission Estimates

Several caveats should be noted with respect to the particulate emission estimates presented here. First, the estimates represent total particulate emissions, without any distinction of particle sizes. Thus, both large particles and small particles are included. Emissions of very large particles are more likely to settle out of the atmosphere and not be measured as total suspended particulate by air quality monitoring equipment. Small and intermediate size particles are more likely to remain airborne and are more efficiently captured by total suspended particulate air monitoring equipment. Small particles are also capable of being inhaled into the human respiratory system, possibly causing adverse health effects. The particulate emission controls that have been employed to date have been most effective in reducing emissions of large and intermediate size particles. The trend in the emissions of small particles is not clearly known. However, it is very doubtful whether small particle emissions have been reduced to the extent that total particulate emissions have been reduced. It should be noted that some small particles may be formed in the atmosphere as the result of various chemical and physical processes. Such particles are not included in the estimated total particulate emissions.

A second caveat is that fugitive particulate emissions (emissions from unconfined sources such as storage piles, material loading, etc.) are incompletely accounted for in the emission totals. Rough estimates of industrial process fugitive emissions are included for some industries. Area source fugitive dust emissions (unpaved roads, construction activities, etc.) are not included at all. Similarly, natural sources of particulate, such as wind erosion or dust, are not included. (An exception is forest fires, some of which result from natural causes). In total, these fugitive emissions may amount to a considerable portion of total particulate emissions. The controls applied to these sources have so far been minimal. Due to the lack of adequate emission factors and emission inventory techniques for these sources, fugitive particulate emissions have not been included in most emission inventories. As additional data become available, it is expected that estimates of fugitive particulate emissions will be included in future emission inventories. It should be noted, however, that a major portion of the fugitive particulate emissions are relatively large particles that are not readily captured by particulate air quality monitors. A mitigating factor which applies to this situation may be that these large particles do not effectively enter into the human respiratory system.

4.2 Sulfur Oxides (SOx)

1940-1970

From 1940 to 1970, major increases in sulfur oxide emissions occurred as the result of increased combustion of fossil fuels such as coal and oil. Industrial process emissions also increased, but to a lesser extent. Sulfur oxide emissions from other source categories decreased, primarily as the result of the obsolescence of coal-fired railroad locomotives and a decrease in coal refuse burning.

1970-1988

Since 1970, total sulfur oxide emissions have declined about 27 percent. This result is due to the use of fuels with lower average sulfur contents, some scrubbing of sulfur oxides from flue gases, and controls on industrial process sources (Table 29, Figure 13). Significant emission reductions from industrial processes have occurred, mostly from non-ferrous smelters and sulfuric acid plants. By-product recovery of sulfuric acid at smelters has increased since 1970 meaning that sulfur oxide emissions that previously would have been released to the atmosphere are recovered as sulfuric acid. Since 1972, new sulfuric acid manufacturing plants have been subject to New Source Performance Standards requirements. These rules have contributed to decreased emissions, as new plants built to meet new product demands or replace old facilities, must achieve more stringent emission control than old facilities. As shown in the tables, since

1970 emissions from electric utilities account for more than half of the total sulfur oxide emissions. Combustion of sulfur-bearing fuels, chiefly coal and residual fuel oil, is primarily responsible for this increase. Figure 14 shows how SO_2 and NO_x emissions from electric utility coal combustion have changed from 1940-1988. Between 1970 and 1988, utility use of coal more than doubled. Emissions from utilities have decreased, however, because fuels with low sulfur content have been used to the extent that they were available. Also, flue gas desulfurization systems have been installed by the late 1970's helped to prevent increases in electric utility emissions. 1988 electric utility emissions would have been approximately 60 percent higher without the operation of flue gas desulfurization controls. The theoretical 1988 national emission estimates given in Table 29 for stationary fuel combustion sources are based on (1) 1988 fuel amounts, (2) fuel sulfur contents that represent 1970 average levels for fuel oil and (3) an estimated average sulfur content of coal that would have been consumed if there were no changes in air pollution regulations since 1970. It is estimated that the average sulfur content of coal burned nationwide would have declined anyway even without new air pollution regulations due to the greater use of coal from the Western U.S., which generally has a lower sulfur content than coal from the Eastern States. On this basis, electric utility emissions would have increased 60 percent. In fact, emissions decreased by 14 percent. Sulfur oxide emissions from other fuel combustion sectors decreased, primarily due to less coal burning by industrial, commercial and residential consumers.

Comments on Sulfur Oxide Emission Estimates

Emissions of sulfur and nitrogen oxides have been identified as precursors of acidic precipitation and deposition. To support Federal research activities on the subject, more detailed historical emissions estimates of sulfur and nitrogen oxides have been developed. Interested readers may wish to review Reference 30, which contains State level estimates of sulfur and nitrogen oxide emissions from 1900 through 1980.

4.3 Nitrogen Oxides (NOx)

1940-1970

Nitrogen oxide emissions result almost entirely from fuel combustion by stationary sources and motor vehicles. From 1940 through 1970, NO_x emissions increased steadily as the result of increased fuel combustion.

1970-1988

Controls applied to sources of NO_x emissions have had a limited effect in reducing emissions through 1988. Table 29 (Figure 13) shows that with the 1970 control level, national NO_x emissions would have been about 39 percent higher than actual 1988 emissions. The emissions from stationary fuel combustion sources largely reflect the actual growth in fuel consumption. For electric utilities, NSPS control requirements have, somewhat, held down the growth in NO_x emissions. Nevertheless, NO_x emissions from electric utilities increased 61 percent from 1970 to 1988. For mobile sources, NO_x emissions were controlled as a result of the Federal Motor Vehicle Control Program (FMVCP). Nitrogen oxide emissions from highway vehicles would have increased 97 percent, had there been no change in control level since 1970. The estimates of actual NO_x emissions show a 3 percent increase. Figure 15 shows how NO_x emissions from major highway vehicle categories have changed from 1970 to 1988.

Figure 14

Emissions of Sulfur and Nitrogen Oxides from Electric Utility Coal Combustion

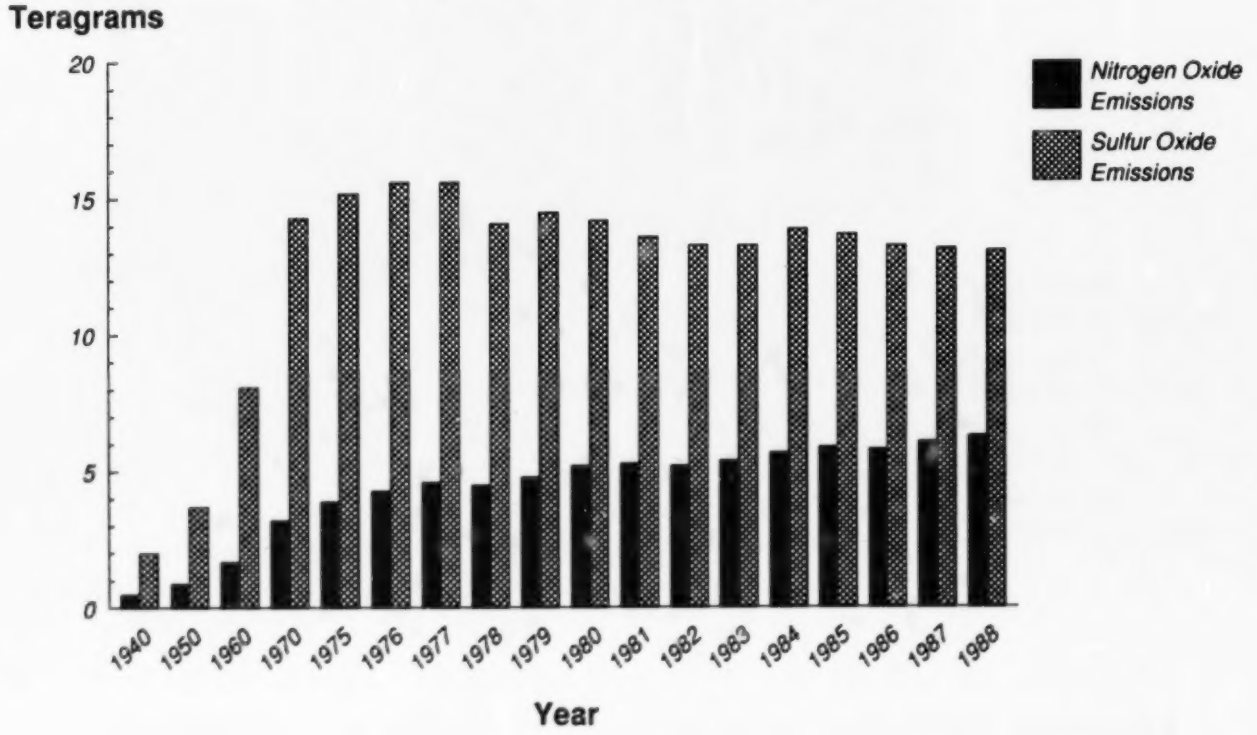
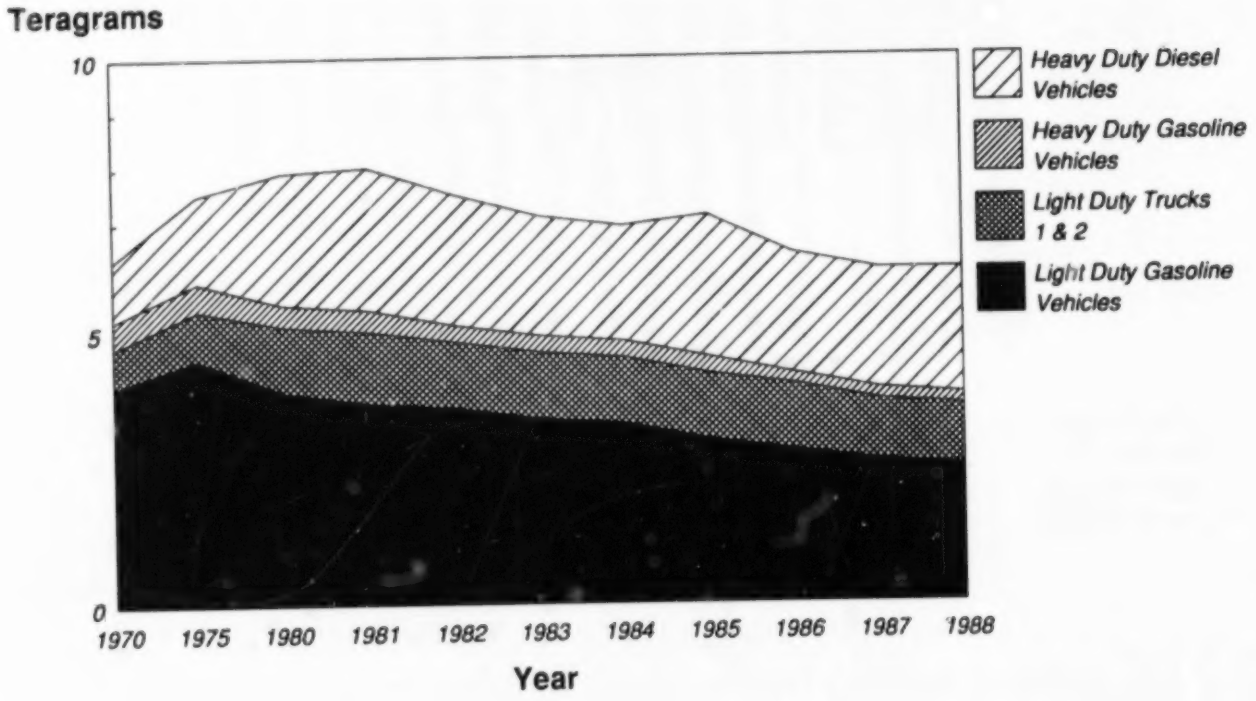


Figure 15

Emissions of Nitrogen Oxides from Highway Vehicles



4.4 Reactive Volatile Organic Compounds (VOC)*

1940-1970

From 1940 through 1970, reactive VOC emissions increased about 65 percent. Major increases in highway vehicle travel and industrial production were chiefly responsible. Emissions from these source categories were about two and a half times higher in 1970 than in 1940. However, emissions from other contributing categoreis--residential fuel combustion and forest fires--declined substantially. In 1940, residential fuel combustion and forest fires accounted for 32 percent of total national reactive VOC emissions. By 1970, their contribution to total reactive VOC emissions had been reduced to 4 percent.

1970-1988

Since 1970, emissions of reactive VOC decreased primarily due to motor vehicle controls and less burning of solid waste. Without controls, a substantial increase in emissions from highway vehicles would have occurred. From 1970 to 1988, vehicle-miles of travel in the U.S. increased by about 81 percent.[4] A 70 percent increase in emissions would have occurred had 1970 control levels remained unchanged. As a result of the controls put in place, reactive VOC emissions from highway vehicles actually decreased 46 percent (Table 29, Figure 13). Figure 16 shows how reactive VOC emission from major highway vehicle categories have changed from 1970-1988. Reactive VOC emissions also decreased due to the substitution of water-based emulsified asphalts (used for road paving) for asphalts liquefied with petroleum distillates (cutback asphalts). This is reflected in the decreased emissions reported for miscellaneous organic solvent use.

Through 1978 these decreases were offset by increases in industrial process emissions. Since then, industrial process emissions have also declined, so that overall total reactive VOC emissions were reduced about 5 percent from 1970 to 1988. Industrial process emissions increased due to higher production levels, particularly in industrial sectors such as petroleum refining, organic chemical production, and industrial uses of organic solvents. However, control procedures employed were effective in limiting the growth in emissions. In addition, source production levels in 1981 through 1983 were relatively low due to poor economic conditions. However, industrial process emissions increased slightly (3 percent) from 1987 to 1988 due to increased industrial activity. Through the mid-1970's, emissions from petroleum product storage and marketing operations also increased as the result of increased demand for petroleum products, particularly motor gasoline. Since 1978, emissions from this source sector are estimated to have decreased as the result of more effective control measures.

**The volatile organic compounds discussed in this document are those defined as having reactive properties. Non-reactive VOCs are not included in this discussion.*

In 1970, reactive VOC emissions from residential fuel combustion were insignificant. However, in the late 1970's emissions began to increase due to the popularity of wood stoves and fireplaces for residential space heating. In 1988, residential fuel combustion accounted for about 4 percent of total reactive VOC emissions.

Comments on Reactive VOC Emission Estimates

Volatile organic compounds along with nitrogen oxides are participants in atmospheric chemical and physical processes that result in the formation of ozone and other photochemical oxidants. Emissions of reactive VOC that are most likely to have a role in such atmospheric processes are included in the reported emissions estimates. Photochemically non-reactive compounds such as methane are not included in the estimated emissions of reactive VOC. Biogenic sources of organic compounds, such as trees and other vegetation, are not included either. Initial estimates are that emissions of reactive VOC from naturally-occurring sources exceed the amount of anthropogenic emissions. However, the extent to which biogenic sources of reactive VOC contribute to oxidant formation, if at all, has not been clearly established.

Ambient concentrations of ozone are typically higher during the summer months. As a result, analysis of seasonal rather than annual, reactive VOC emissions may be more appropriate to understand the relationship between reactive VOC emissions and high ozone concentrations in the atmosphere. Sources such as residential space heating, which occurs primarily during the winter, would have little impact on summer ozone levels.

4.5 Carbon Monoxide (CO)

1940-1970

From 1940 through 1970, the relative contribution by the various source categories to total CO emissions changed considerably. In 1940, highway vehicles contributed only about 27 percent of carbon monoxide emissions. Residential fuel combustion (primarily of wood and coal), forest fires and other burning (agricultural crop residues and coal refuse) contributed about 50 percent of total CO emissions. From 1940 to 1970, highway vehicle emissions nearly tripled, while emissions from residential fuel combustion and miscellaneous burning sources decreased substantially. As a result, in 1970 highway vehicles accounted for 64 percent of total CO emissions. Industrial process CO emissions increased from 1940 to 1970 by about 35 percent. The largest increase occurred in the petroleum refining sector, primarily as the result of expansion of catalytic cracking capacity to meet increased demand for gasoline and other middle distillates.

1970-1988

Since 1970, highway motor vehicles have been the largest contributing source of CO emissions. Figure 17 shows how CO emissions from major highway vehicle categories have changed from 1970-1988. The implementation of the Federal Motor Vehicle Control Program (FMVCP) has been successful in reducing CO emissions since the early 1970's. From 1970 through 1978, motor vehicle miles of travel increased 38 percent, but because of controls on new vehicles, total CO emissions from highway vehicles decreased 15 percent. From 1978 to 1980, VMT declined by 1.7 percent. This lack of growth in vehicle travel, together with an increased degree of control because of stricter emission standards for new vehicles and the gradual disappearance of older uncontrolled vehicles from the vehicle fleet, produced an estimated 12 percent drop in highway vehicle emissions in the two year period from 1978 to 1980. Since 1980, VMT have grown each year. From 1980 to 1988, VMT increased by 33 percent. However, due to the FMVCP controls, CO emissions from highway vehicles actually decreased 30 percent during this period. Overall from 1970 to 1988, without the implementation of FMVCP, highway vehicle emissions would have increased 61 percent (Table 29, Figure 13). By comparison, actual emissions are estimated to have decreased 48 percent.

CO emissions from other sources have also generally decreased. In 1970, emissions from burning of agricultural crop residues were greater than in more recent years. Solid waste disposal emissions have also decreased as the result of implementation of regulations limiting or prohibiting burning of solid waste in many areas. Emissions of CO from stationary source fuel combustion occur mainly from the residential sector. These emissions were reduced somewhat through the mid-1970's as residential consumers converted to natural gas, oil, or electric heating equipment. Recent growth in the use of residential wood stoves has reversed this trend, but increased CO emissions from residential sources continue to be small compared to highway vehicle emissions. Nevertheless, in 1988 residential wood combustion accounted for about 10 percent of national CO emissions, more than any source category except highway vehicles. CO emissions from industrial processes have generally been declining since 1970 as the result of the obsolescence of a few high-polluting processes such as manufacture of carbon black by the channel process and installation of controls on other processes. However, industrial process emissions increased slightly (4 percent) from 1987 to 1988 due to increased industrial activity.

Figure 16

Emissions of Reactive Volatile Organic Compounds from Highway Vehicles

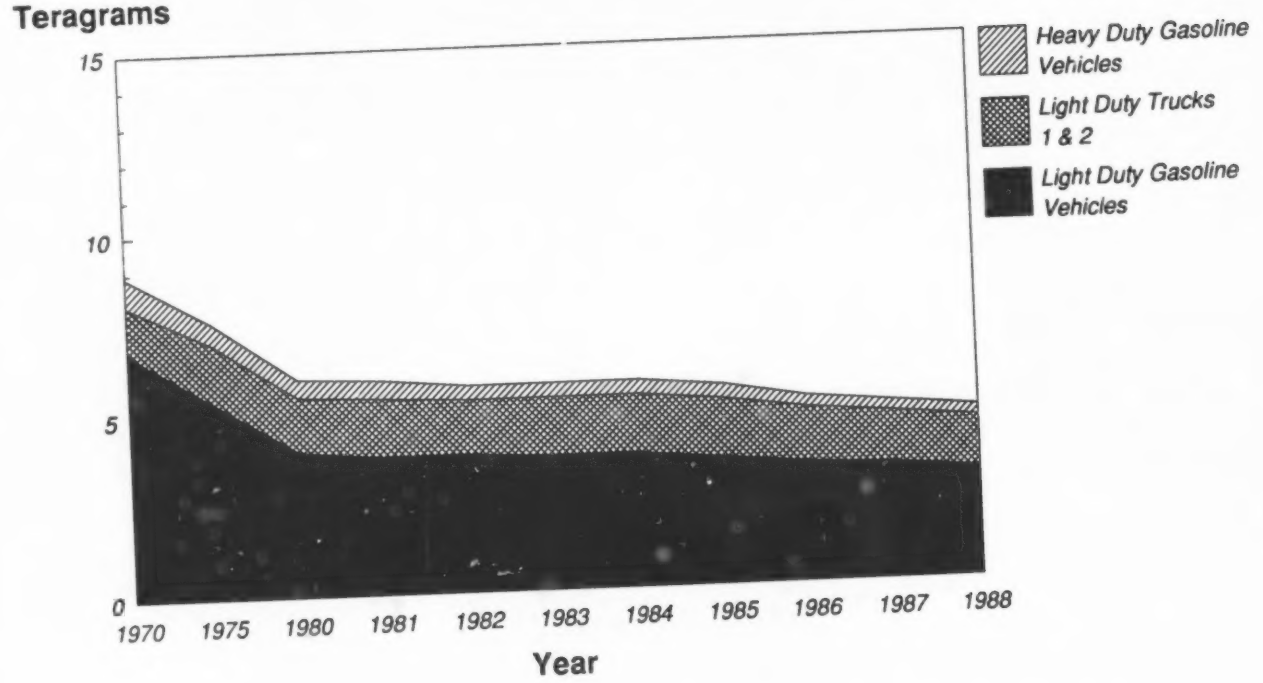
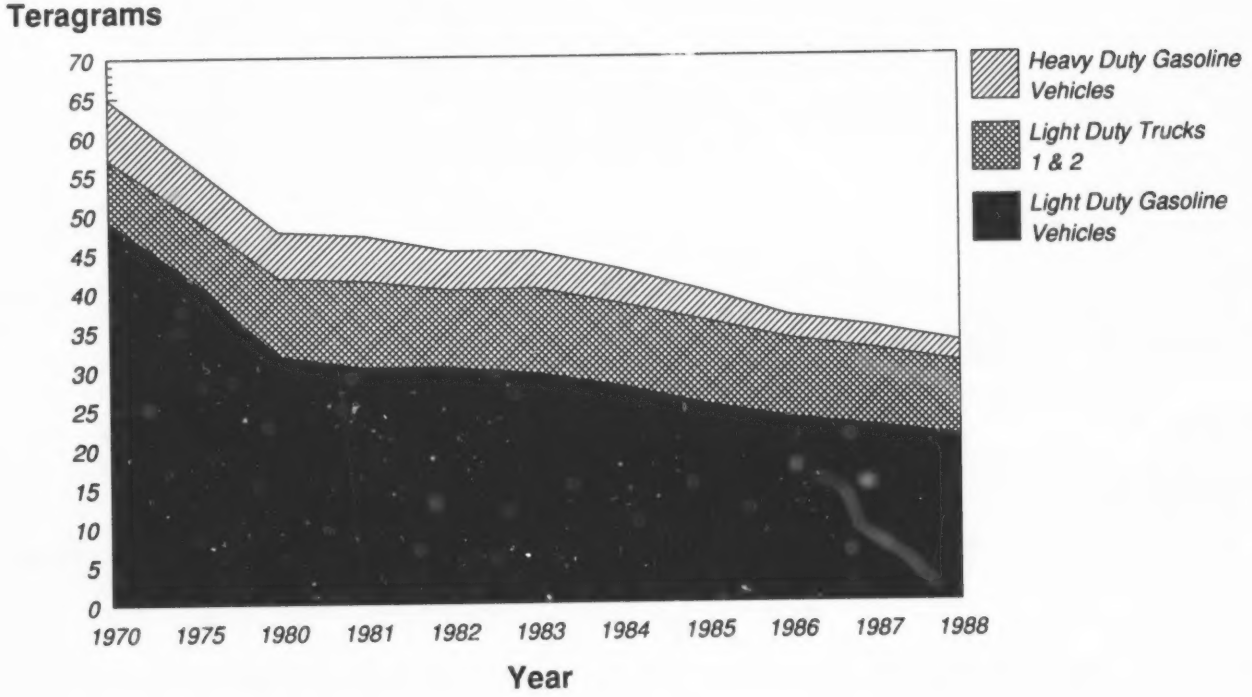


Figure 17

Emissions of Carbon Monoxide from Highway Vehicles



4.6 Lead

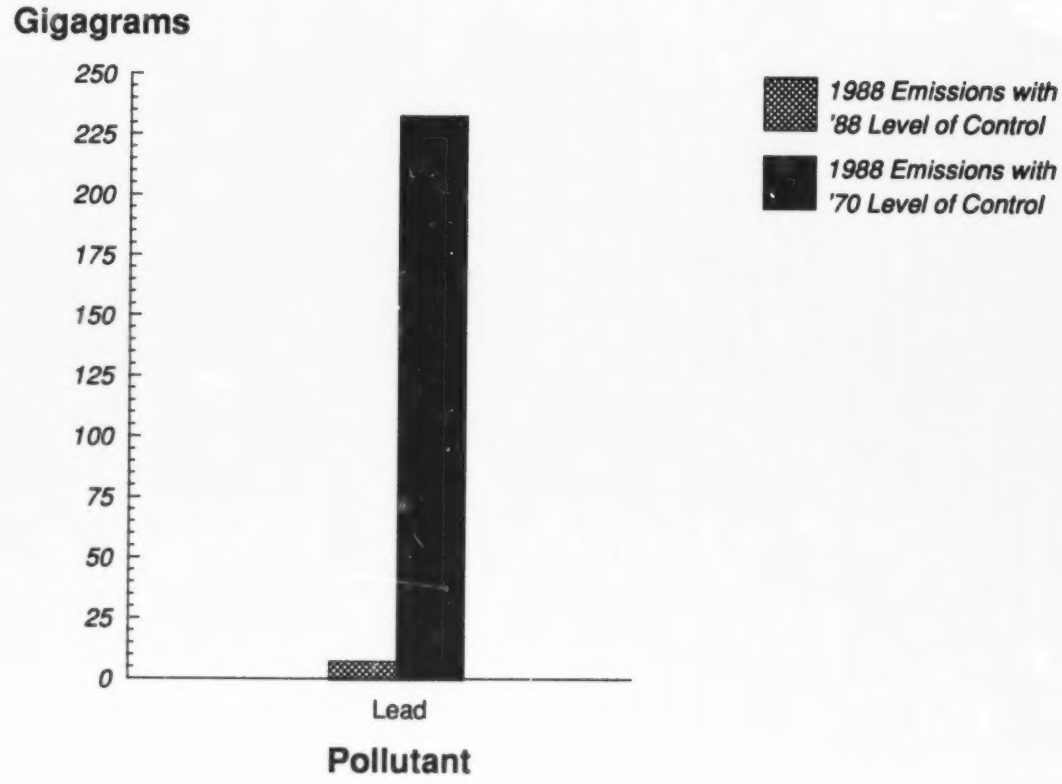
1970-1988

The emissions of lead have decreased due to the implementation of the Federal Motor Vehicle Control Program (FMVCP). The implementation of FMVCP has resulted in the use of catalytic converters to reduce NO_x, VOC, and CO emissions and has required the use of unleaded gasoline for vehicles with converters. From 1970 through 1975, the highway use of gasoline increased 16 percent, but because of the decrease in lead content in leaded gasoline, lead emissions from highway vehicles decreased 24 percent. From 1975 to 1988, the percent of unleaded gasoline sales increased from 13 to 82 percent, and the lead emissions decreased 98 percent (Table 12 and 29, Figure 18). A major reduction in lead emissions occurred between 1984 and 1986 when EPA issued rules which required petroleum refiners to lower the lead content of leaded gasoline to 0.5 grams per gallon in 1985 and .1 grams per gallon in 1986. Previously, the lead content of leaded gasoline had been 1.1 grams per gallon or more. From 1970 through 1988, off highway consumption of gasoline decreased 31 percent and associated lead emissions decreased 98 percent.

Lead emissions also decreased from other sources. The 95 percent decrease in stationary source fuel combustion is a result of the decrease in lead concentration in waste oil utilized in industrial boilers. Lead emissions decreased 92 percent for industrial processes from 1970 through 1988. Part of this decrease reflects the changes that result from installation of air pollution control equipment. As shown in Tables 12 and 29, the change in emissions as a result of changes in operating rates would be a 34 percent reduction. However, industrial process emissions increased slightly (5 percent) from 1987 to 1988 due to increased industrial activity. Lead emissions from solid waste disposal have decreased 63 percent from 1970 through 1988 as a result of the decreased amount of solid waste disposed of by incineration.

Figure 18

Theoretical Estimate of 1988 Nationwide Emissions of Lead with 1970 Control



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16. ABSTRACT

This report presents estimates of trends in nationwide air pollutant emissions for six major pollutants: particulate (PM/TSP), sulfur oxides, nitrogen oxides, reactive volatile organic compounds, carbon monoxide, and lead. Estimates are provided for major categories of air pollution sources. A short analysis of emission trends is given, along with a discussion of methods used to develop the data.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Trends, emissions, inventory, air pollutants, nationwide, particulate (PM/TSP), sulfur oxides, nitrogen oxides, reactive volatile organic compounds, carbon monoxide, lead, miscellaneous sources, controllable emissions, point sources, pollution estimates		

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